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Vitamin-B and Vitamin-G Content of Cereals

By Rossleene Arnold Hetler, Clara Rocke Meyer,
and Dorothy Hussemann

UNIVERSITY OF ILLINOIS
AGRICULTURAL EXPERIMENT STATION
BULLETIN 369

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Urbana, Illinois May, 1931

Publications in the Bulletin series report the results of investigations made or sponsored by the Experiment Station

Vitamin-B and Vitamin-G Content of Cereals

ROSSLEENE ARNOLD HETLER, CLARA ROCKE MEYER, and DOROTHY HUSSEMANN[a]

THE FACT that cereals play a large part in the nutrition of both man and animals makes the vitamin content of this class of foods of basic importance. The data recorded in the present investigations have been obtained from observations made in the Home Economics laboratory at the University of Illinois during the years 1927 to 1930. A series of studies have been in progress concerning the nutritive condition of animals when corn, oats, wheat, or rice polishings have been included in the diet, either as a sole source of vitamins B and G or as the sole source of one or the other of these two vitamins.

When the work was begun in 1927, Sherman's standard method[22]* was used for the determination of vitamin B, and no distinction was made between the two factors of the "vitamin-B complex." During the progress of the investigation, however, definite recognition of vitamins B and G was made, and thus it was found necessary to introduce changes in the methods of procedure. A tentative method, both for the determination of vitamin B and of vitamin G, was developed and applied to the determination of the content of these vitamins in some of the cereals and cereal products. It was found that the inclusion of 25 percent oats, corn, or wheat in the diet probably provides an adequate supply of vitamin B for growth if plenty of vitamin G is incorporated in the basal diet. On the other hand, at least 50 percent of the diet must be made up of any one of these cereals if sufficient vitamin G is to be supplied for approximately normal growth. This explains the fact that in the earlier work it was found necessary to include the cereal to the extent of 50 or 60 percent of the diet if the diet was to supply sufficient "vitamin-B complex" for normal growth.

The investigation was extended to include observations on the nutritive requirements of lactation. Whereas a diet made up of 25 percent of any of the cereals supplied adequate vitamin B for growth and maintenance, it was necessary to include in the diet of a lactating rat at least 50 percent cereal in order to supply adequate vitamin B for the growth of the young. Sufficient vitamin G could be furnished for successful lactation if, in addition to the cereal, the diet included 15 percent autoclaved yeast. It seems justifiable to conclude from the

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above observations that more of the B and G vitamins are necessary for lactation than for growth and maintenance.

It is of particular interest to note the relative amounts of vitamins B and G in the different cereals. Since the diet must include at least 25 percent of either oats, wheat, or corn if it is to provide an adequate supply of vitamin B, it is clear that the vitamin-B content of cereals is rather low. Twice as much cereal, or 50 percent, is necessary, however, to supply sufficient vitamin G for approximately normal growth, and it thus appears that vitamin G is the limiting factor of the "vitamin-B complex" of cereals. Whether there is a real difference in the content of vitamins B and G in the cereals, or whether the relative amounts of vitamins B and G needed by the rat differ, is a subject for further investigation. It is very possible that an interrelationship exists in the needs of the rat for these two vitamins, and thus that we are testing this factor rather than the content of the vitamins in the cereals and cereal products.

REVIEW OF LITERATURE

Not only the discovery of the antineuritic factor, vitamin B, but also the recognition of the pellagra-preventive factor, vitamin G, has come thru the study of deficiency diseases occurring on a restricted cereal diet. In 1897 Eijkman[7]* first attributed the disease beriberi to the deficiency occurring when the diet was made up largely of polished rice. Goldberger[11]* in 1925, studying the prevention of pellagra, found that the diets of pellagrins are composed largely of wheat flour, rice flour, and corn meal.

In 1916 McCollum, Simmonds, and Pitz,[16]* using whole wheat as a source of vitamin B in the diet of growing animals, showed that this vitamin is contained in wheat in a very high concentration. The next year[17]* these investigators discovered that: "The oat kernel, like unpolished rice, wheat, wheat germs, maize kernel, alfalfa leaves, cabbage, and clover leaves, contains a liberal supply of water-soluble B, the preparations of which induce relief from polyneuritis." In 1918 Steenbock, Kent, and Gross[25]* concluded that there is an abundance of water-soluble vitamin B in barley. Bell and Mendel[2]* in 1922 decided that wheat is comparatively low in vitamin B, for about 40 percent of this cereal in the diet was found necessary for normal growth in the rat. Steenbock, Sell, and Nelson[26]* in 1923 confirmed this observation but found that even more than 40 percent of the diet of a rat must consist of cereals if normal growth is to be produced. The rats were housed in raised-bottom cages so that they could not supplement their diets by consumption of excreta. Under such conditions 60 percent of

the diet, it was shown, must be furnished by any of these grains in order to supply enough vitamin B for maximum growth. Croll and Mendel[6]* in 1925 induced normal growth in rats when the only source of vitamin B was supplied by a ration which included 25 to 30 percent white or yellow maize. Recent work by Hunt[13]* shows that growth occurs when rats are fed on a vitamin-B-free ration of which 15 percent is wheat or corn if this ration is supplemented with autoclaved yeast. Hunt's work followed observations by Osborne and Mendel, 1919,[20]* Mitchell, 1919,[18]* Emmett and Luros, 1920,[8]* and others, who had expressed the opinion that vitamin B might be made up of two parts. Hunt believed the cereals supplied plenty of the antineuritic vitamin when fed at a 15-percent level but that autoclaved yeast was necessary to supply the limiting factor, vitamin G. In 1926 Smith and Hendrick[24]* attempted to correct the deficiency of a diet composed of oats, casein, vitamin A, and inorganic salts. These investigators found that the above diet was materially remedied by a small addition of dried brewers' yeast. It was not clear whether the improvement was due to yeast protein, water-soluble vitamin, or to some unknown factor. In attempting to rule out vitamin B, the basal ration was supplemented with dried brewers' yeast, autoclaved for six hours at 15 pounds pressure, which procedure, as was shown by tests, completely destroyed vitamin B. Rats responded with growth. It was therefore demonstrated that autoclaving brewers' yeast, tho destroying its vitamin-B content, did not impair its efficiency in supplementing the oat deficiency. That the oat kernel was not deficient in vitamin B but in some other factor which was present in brewers' yeast and which withstood prolonged autoclaving, was the logical conclusion.

In 1927 Chick and Roscoe[3]* tested wheat embryo, autoclaved wheat embryo, alcoholic extracts of wheat, and other substances for the two factors called by them B_1 and B_2. They concluded that there is an antineuritic vitamin which prevents or cures collapse, including paralysis, and a second factor which is pellagra-preventive. The two taken together are growth-promoting. Salmon, Guerrant, and Hays in 1928,[21]* using the velvet bean, found that by controlling the hydrogen-ion concentration, the B-P factor, vitamin B, could be adsorbed on fuller's earth more completely than the P-P factor, vitamin G. In 1928 Evans and Burr[10]* again differentiated between the two factors by using an alcoholic extract of rice polishings in addition to a purified diet, and thereby produced no growth, yet no neuritis. By adding yeast, growth resulted. Munsell[19]* in 1929 found in testing rice polishings that it takes more of the rice polishings to supply the amount of vitamin G required by the rat for optimum growth than it does to

supply the needed amount of the antineuritic vitamin. Hauge and Carrick[12]* showed corn to be rich in the antineuritic substance but poor in the growth-promoting substance. Aykroyd and Roscoe[1]* in 1929 reported data concerning the B_2 (G) content of several foods. They found that wheat and maize are poor in vitamin B_2, "the maize being on the whole the lower in the samples examined; in wheat the germ and bran are better sources than the endosperm, and about equal to each other; in maize the germ is not so rich a source, but whole maize is better than maize endosperm."

I. VITAMIN-B COMPLEX IN EMBRYO AND ENDOSPERM ENDS OF HAND-DISSECTED OAT KERNELS[a]

In studying the vitamin-B complex in embryo and endosperm ends of hand-dissected oat kernels, whole hull-less oats obtained from the Agronomy Department of the College of Agriculture were carefully sorted by hand to eliminate all foreign matter. The kernels were then cut with a scalpel into two sections, there being left at the embryo end about one-third of the whole kernel by weight and at the endosperm

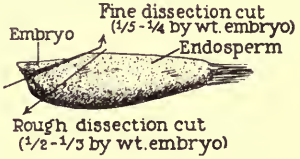

FIG. 1.—HAND-DISSECTED EMBRYO AND ENDOSPERM SECTIONS OF OAT KERNEL
By using the fine dissection cut, an embryo fraction was obtained which was almost, if not entirely, free from endosperm.

end about two-thirds of the whole kernel. This dissection gave an embryo fraction which was far from being free from adhering endosperm. Later it was found necessary to make a more careful dissection of the two structures, embryo and endosperm. By a curved cut an embryo fraction was obtained which was almost, if not entirely, free from endosperm. This dissection resulted in an embryo fraction which was approximately one-fifth to one-fourth of the whole kernel by weight. The fractions were finely ground and stored in glass jars.

In the vitamin test an attempt was made to follow the technic recommended by Sherman and MacArthur, 1927,[23]* for the quantitative determination of vitamin B. Young rats from the laboratory stock

[a]This work was carried on in 1927-28.

TABLE 1.—EFFECT OF YEAST AS SOURCE OF VITAMIN-B COMPLEX IN DIET

Rat No. and sex	Average daily basal food intake	Average daily total food intake	Test period	Average daily gain or loss in weight
	gms.	*gms.*	*days*	*gms.*
Control animals, .4 gram yeast daily				
779 ♀	8.2	8.6	32	+2.5
787 ♂	7.4	7.8	32	+4.1
754 ♀	6.8	7.2	56	+1.8
723 ♂	9.0	9.4	46	+3.0
626 ♂	7.2	7.6	43	+2.6
625 ♀	5.7	6.1	46	+2.1
616 ♂	6.8	7.2	43	+2.2
607 ♂	7.5	7.9	50	+2.3
599 ♀	7.4	7.8	56	+2.0
Control animals, no yeast				
771 ♂	3.6	No	30	− .3
763 ♀	4.4	supplement	30	− .5
755 ♂	3.0		45	− .3
747 ♀	3.0		33	0
724 ♂	3.5		31	− .1
627 ♂	2.4		35	− .3
624 ♂	2.6		46	− .2
617 ♂	3.3		37	− .2
609 ♂	3.1		37	− .1
601 ♀	2.7		37	− .2

TABLE 2.—EFFECT OF WHOLE OATS AS SOURCE OF VITAMIN-B COMPLEX IN DIET

Rat No. and sex	Daily amount whole oats	Average daily basal food intake	Average daily total food intake	Percent whole oats was of total food intake	Average daily gain or loss in weight
	gms.	*gms.*	*gms.*	*perct.*	*gms.*
740 ♂	3	4.7	7.7	39	+1.5
739 ♂	3	5.9	8.9	33	+1.9
542 ♂	1	5.3	6.3	16	+ .7
541 ♀	1	4.2	5.2	19	+ .6
619 ♂	½	3.5	4.0	12.5	+ .3
618 ♀	½	4.7	5.2	9.6	+ .4
598 ♂	½	5.1	5.6	9.1	+ .5
597 ♀	½	4.1	4.6	10.8	+ .5
596 ♂	½	5.3	5.8	8.6	+ .7
595 ♀	½	3.9	4.4	11.3	+ .4
594 ♀	½	4.0	4.5	11.1	+ .6
765 ♂	⅓	4.4	4.7	7.1	+ .2
764 ♂	⅓	4.3	4.6	7.1	0
759 ♀	⅓	4.6	4.9	6.5	+ .4
758 ♂	⅓	4.9	5.2	6.3	+ .3
781 ♀	⅓	4.6	4.9	6.7	+ .2
780 ♀	⅓	3.9	4.2	7.7	0
773 ♂	⅓	4.6	4.9	6.7	− .1
772 ♀	⅓	5.7	6.0	5.5	− .1
749 ♂	¼	5.1	5.4	4.7	+ .4
748 ♂	¼	4.1	4.4	5.6	0
742 ♂	¼	3.1	3.4	7.4	0
741 ♀	¼	3.3	3.6	7.0	+ .1
734 ♀	¼	5.3	5.5	4.5	+ .3
733 ♂	¼	4.8	5.1	4.9	+ .3
726 ♂	¼	3.5	3.8	6.6	0
725 ♀	¼	3.3	3.6	7.0	0
628 ♂	¼	3.4	3.7	6.8	− .1
629 ♀	¼	3.3	3.6	7.0	0
611 ♀	¼	3.3	3.6	7.0	0
610 ♂	¼	3.7	4.0	6.3	+ .2

colony were used. When four weeks old and weighing from 40 to 50 grams, they were placed in individual, raised-bottom, wire-mesh cages. A basal diet was given *ad libitum,* as was also distilled water. The basal diet, as given below, was of the type in general use in 1927 for vitamin-B testing:

	percent
Casein (Harris, free from water-soluble B)	18
Lard	22
Cornstarch	56
Osborne-Mendel salt mixture	4

Cod-liver oil (Squibb's Grade A), 1 cc. every 4 days

TABLE 3.—EFFECT OF OATS ENDOSPERM AS SOURCE OF VITAMIN-B COMPLEX IN DIET

Rat No. and sex	Daily amount oats endosperm	Average daily basal food intake	Average daily total food intake	Percent oats endosperm was of total food intake	Average daily gain or loss in weight
	gms.	*gms.*	*gms.*	*percl.*	*gms.*
767 ♀	1/3	3.4	3.7	8.8	0
766 ♂	1/3	4.5	4.8	6.8	+ .3
757 ♀	1/3	5.3	5.6	5.8	+ .2
756 ♂	1/3	4.0	4.3	7.6	0
783 ♂	1/3	3.9	4.2	7.7	0
782 ♀	1/3	4.3	4.6	7.1	− .1
775 ♂	1/3	4.6	4.9	6.7	0
774 ♀	1/3	4.8	5.1	6.4	0
751 ♂	1/4	3.6	3.9	6.4	0
750 ♀	1/4	4.4	4.7	5.3	+ .6
744 ♂	1/4	3.4	3.7	6.8	− .1
743 ♂	1/4	3.8	4.1	6.1	+ .1
736 ♀	1/4	4.9	5.2	4.8	+ .2
735 ♂	1/4	4.8	5.1	4.9	+ .2
728 ♀	1/4	3.2	3.5	7.2	− .2
727 ♂	1/4	3.7	4.0	6.3	− .4
623 ♀	1/4	3.1	3.4	7.3	+ .1
622 ♂	1/4	3.2	3.5	7.2	0
615 ♀	1/4	3.9	4.2	6.0	+ .1
614 ♂	1/4	2.7	3.0	8.4	− .1
603 ♂	1/4	3.0	3.3	7.6	− .1
602 ♂	1/4	5.1	5.4	4.6	− .2
600 ♀	1/4	3.6	3.9	6.5	0
631 ♀	1/8	3.0	3.1	3.8	− .2
630 ♂	1/8	2.9	3.0	3.9	0

The finely ground supplements of the oat kernel were fed separately in the following amounts daily:

	grams
Whole oats (ground)	3, 1, 1/2, 1/3, 1/4
Endosperm ends (ground)	1/3, 1/4, 1/8
Embryo ends (rough dissection, ground)	1/3, 1/4, 1/8
Embryo ends (fine dissection, ground)	1/4

Control animals were maintained on the basal diet with and without a supplement of brewers' yeast. The basal diet was free from the antineuritic vitamin but, as has been shown by Evans and Burr,[10]* furnished some vitamin G in the cornstarch and lard. The weights of

the animals, together with food intake, were recorded every four days.

Since in these earlier experiments no attempt was made to differentiate between vitamins B and G, the findings will be discussed in terms of the vitamin-B complex. The data obtained indicate clearly: first, that the vitamin-B complex is distributed thruout the oat kernel; and

TABLE 4.—EFFECT OF OATS EMBRYO AS SOURCE OF VITAMIN-B COMPLEX IN DIET

Rat No. and sex	Daily amount oats embryo	Average daily basal food intake	Average daily total food intake	Percent oats embryo was of total food intake	Average daily gain or loss in weight
		Rough embryo			
	gms.	*gms.*	*gms.*	*perct.*	*gms.*
769 ♂	1/8	4.2	4.5	7.2	+ .4
768 ♂	1/8	4.7	5.0	6.5	+ .6
761 ♂	1/8	4.0	4.3	7.6	+ .5
760 ♂	1/8	4.0	4.3	7.6	+ .2
785 ♀	1/8	3.8	4.1	7.9	0
784 ♂	1/8	4.9	5.2	6.3	+ .4
777 ♀	1/8	4.2	4.5	7.2	+ .3
776 ♀	1/8	4.7	5.0	6.5	+ .3
753 ♀	1/4	4.4	4.7	5.3	+ .3
752 ♀	1/4	4.2	4.5	5.6	+ .1
746 ♀	1/4	3.1	3.4	7.3	+ .2
745 ♂	1/4	4.1	4.4	5.7	+ .4
738 ♀	1/4	5.0	5.3	4.7	− .1
737 ♂	1/4	5.1	5.4	4.7	+ .3
730 ♀	1/4	3.3	3.6	6.9	0
729 ♂	1/4	2.9	3.2	7.8	− .2
621 ♀	1/4	3.3	3.6	6.9	0
620 ♂	1/4	3.3	3.6	6.9	+ .1
613 ♀	1/4	3.9	4.2	6.0	0
612 ♂	1/4	3.7	4.0	6.5	0
604 ♂	1/4	3.9	4.2	6.0	0
605 ♂	1/4	4.4	4.7	5.3	+ .1
606 ♀	1/4	4.5	4.8	5.2	+ .2
608 ♀	1/4	3.5	4.1	6.6	+ .1
		Close dissection			
770 ♀	1/4	5.1	5.4	4.7	+ .5
762 ♀	1/4	5.6	5.9	4.3	+ .3
786 ♂	1/4	5.7	6.0	4.2	+ .4
778 ♂	1/4	5.1	5.4	4.7	+ .4
732 ♂	1/4	6.4	6.9	3.8	+ .7
731 ♂	1/4	5.0	5.3	4.7	+ .5
		Rough dissection			
632 ♂	1/8	3.2	3.3	3.6	− .2
633 ♂	1/8	2.5	2.6	4.5	− .1

second, that a greater concentration of the vitamin complex undoubtedly occurs in the embyro, or germ section of the oat grain, than in the endosperm of the kernel (Tables 1 to 5, Fig. 2).

The first conclusion above is based on the fact that animals receiving even the smallest amount of endosperm, 1/8 gram daily, fared better than the negative control animals. Many of the animals receiving the oat supplements, however, died before the end of the eight-week experimental period, but in every case the animal lived longer and was in a

better nutritive condition than any negative control animal. More significant than the above, however, is the evidence of the greater concentration of the vitamin complex in the embryo section of the oat kernel. In almost every case, even with the rough-cut section of the embyro, the animal made a better gain than did the animals receiving

TABLE 5.—SUMMARY OF RESULTS OBTAINED WHEN YEAST, WHOLE OATS, OATS ENDOSPERM, OR OATS EMBRYO WERE USED IN DIET AS SOURCE OF VITAMIN-B COMPLEX

Number of rats	Daily amount supplement	Average daily basal food intake	Average daily total food intake	Percent supplement was of total food intake	Average daily gain or loss in weight
Positive control, yeast					
	gms.	*gms.*	*gms.*	*perct.*	*gms.*
9	.4	7.3	7.7	5.2	+2.5
Negative control					
10	None	3.2	3.2	0	− .3
Whole oats					
2	3	5.3	8.3	36.0	+1.7
2	1	4.8	5.8	17.0	+ .6
7	½	4.4	4.9	10.0	+ .5
8	⅓	4.6	4.9	6.7	+ .1
12	¼	3.9	4.1	6.0	+ .1
Oats endosperm					
8	⅓	4.4	4.7	7.0	+ .1
15	¼	3.7	4.0	6.0	0
2	⅛	3.0	3.1	4.0	− .1
Oats embryo (rough)					
8	⅓	4.3	4.6	7.0	+ .3
16	¼	3.8	4.1	6.0	+ .1
2	⅛	2.8	2.9	4.3	− .2
Oats embryo (close)					
6	¼	5.5	5.8	4.3	+ .5

the supplements of endosperm. Where ⅓ or ¼ gram daily of the supplements was fed, several interesting findings are apparent in the tabulated data. The intake of the basal diet was very nearly the same whether the animal received the embryo or the endosperm supplement, and thus the greater gain in weight of the animals receiving the roughly dissected embryo was not due to an increased consumption of food. In the case of the animals receiving the closely dissected embryo, ¼ gram daily, the intake of basal food was greater and a correspondingly greater increase in weight resulted. The rate of growth was such that at the end of the eight-week period these animals were in a condition comparable with that of animals receiving ½ or 1 gram daily of the

whole oats, and they appeared much better than animals receiving ⅓ gram daily of the roughly dissected embryo.

The attempt made in these experiments[23]* to give just enough of the supplement to maintain a constant weight in the animals for an eight-week period was unsuccessful. The animals always exhibited an

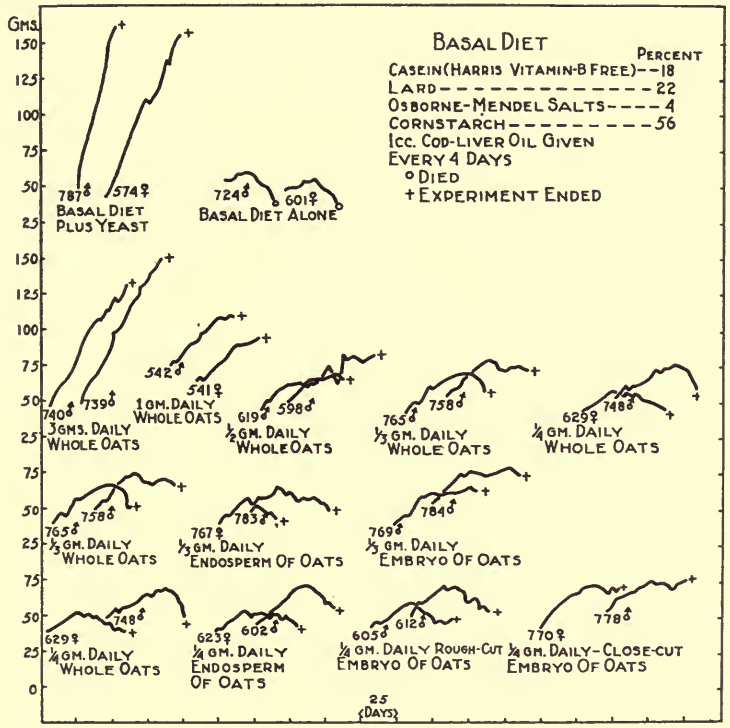

FIG. 2.—WEIGHT CURVES OF RATS RECEIVING WHOLE OATS, OATS ENDOSPERM, AND ROUGH- AND CLOSE-CUT OATS EMBRYO AS SOURCES OF VITAMIN-B COMPLEX

Slightly better growth was obtained with ⅓ gram daily of rough-cut embryo or ¼ gram daily of close-cut embryo as a source of the vitamin-B complex in the diet than with the same amounts of whole oats or oats endosperm. Good growth was obtained with 3 grams daily of whole oats as a source of the vitamin-B complex. Animals receiving even the smallest daily allowance of whole oats (¼ gram daily) fared better than the animals receiving the basal diet alone.

initial gain in weight followed either by a sudden decline and death when very small amounts of the vitamin were given, or by a more gradual gain or loss in weight when more of the supplement was given. It is probable that the experiments were sufficient in number to mini-

mize the effects of individual variations, especially in the cases where ⅓ or ¼ gram of the supplements was given. It may therefore be concluded that the vitamin-B complex is present both in the endosperm and in the embryo of hull-less oats, occurring in greater concentration in the embryo section of the kernel.

II. VITAMIN-B VALUE OF WHOLE HULL-LESS OATS, WHOLE HULLED OATS, OAT PRODUCTS, WHOLE YELLOW CORN, AND WHOLE WHEAT

Young rats from the stock colony weighing 40 to 50 grams were placed in individual, raised-bottom, screen-mesh cages. The diet, as indicated on growth-curve charts, was given *ad libitum.* All animals were under observation as to outward signs of nutritional condition, and were weighed every four days. The food intake was recorded simultaneously with the weighing of the animal.

The cereals or cereal products were incorporated in a diet that was otherwise free from vitamin B. Autoclaved yeast was used as a source of vitamin G. The yeast,[a] placed in uncovered petri dishes to a depth of about ½ inch, was autoclaved for five hours at 120° C. and 15 pounds pressure, dried at room temperature, and then ground to a fine powder. The autoclaved yeast was given in amounts approximating .4 to .5 gram daily.

The whole hull-less oats used were carefully cleaned by hand as described on page 170. They were obtained, as were the Reid Yellow Dent corn and Turkey Red Winter wheat, from the Agronomy Department of the College of Agriculture. The oat products which were tested are produced from a variety of hulled oats. The hulls were removed from these oats by first grinding coarsely, then sifting out the hulls in a sieve. The oat products used were oat groats, "Quaker" oats, and "Quick Quaker" oats. The oat groats, dried and hulled in the commercial process, are slightly broken, with an accompanying loss of a portion of the germ. The "Quaker" oats and the "Quick Quaker" oats are subjected to prolonged high temperature in order to minimize the time of the cooking period when used for human consumption.

The data presented in Table 6 and in the weight curves (Figs. 3 and 4) demonstrate that the growth of animals receiving whole oats or oat products in a diet otherwise free from vitamin B is always increased by the addition of autoclaved yeast to the diet. The acceler-

[a]Dry powdered yeast foam obtained from the Northwestern Yeast Company, Chicago.

ated growth, which occurred in all animals when any level of the whole oats was supplemented by autoclaved yeast, was of short duration in the cases where lower levels of cereal were fed. The data have been

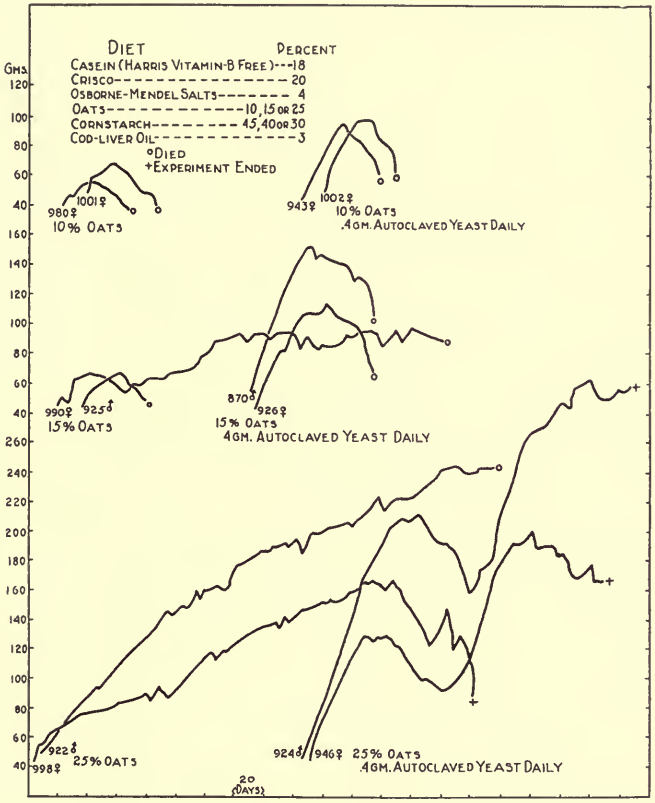

FIG. 3.—WEIGHT CURVES OF RATS RECEIVING (1) OATS AS SOLE SOURCE OF VITAMINS B AND G; (2) OATS AS SOLE SOURCE OF VITAMIN B WITH AUTOCLAVED YEAST FURNISHING VITAMIN G

Increased growth always resulted when .4 gram of autoclaved yeast supplemented the cereal of the basal diet, which included Crisco and cornstarch.

tabulated, therefore, to show the rate of growth and food intake early in the experimental period, or over the first twenty days, as well as during the entire period.

A minimum of 25 percent whole oats or oat products in the diet (or an amount approximating 1½ grams daily) supplemented by autoclaved yeast for vitamin G is shown by these results to be necessary to

TABLE 6.—EFFECTS OF VARYING LEVELS OF OATS AS SOURCE OF VITAMIN B IN DIET WHEN AUTOCLAVED YEAST WAS USED AS SOURCE OF VITAMIN G
(Crisco and cornstarch were used in the diet)

Rat No. and sex	During first twenty days: Average daily amount cereal	During first twenty days: Average daily food intake	During first twenty days: Average daily gain or loss in weight	During entire test period: Average daily amount cereal	During entire test period: Average daily food intake	During entire test period: Average daily gain or loss in weight	Test period	Condition at end of test
			10 percent oats without autoclaved yeast					
	gms.	*gms.*	*gms.*	*gms.*	*gms.*	*gms.*	*days*	
940 ♂....	.5	4.7	+1.2	.4	3.7	− .3	38	Dead
1001 ♀...	.6	5.6	+1.1	.3	3.5	− .1	48	Dead
980 ♀....	.4	3.9	+ .8	.4	2.7	− .1	47	Paralyzed
			10 percent oats plus .4 gram autoclaved yeast daily					
941 ♂....	.6	5.9	+2.3	.5	5.0	+ .2	49	Dead
942 ♀....	.6	5.9	+2.5	.5	5.3	+ .2	48	Humped, wobbly
943 ♀....	.6	5.8	+2.2	.3	3.5	+ .2	53	Convulsive
981 ♀....	.5	4.5	+1.7	.4	3.9	+ .3	54	Convulsive
996 ♀....	.5	5.3	+2.3	.4	3.9	+ .5	54	Humped, paralyzed
997 ♀....	.5	5.2	+2.0	.3	3.4	+ .2	54	Paralyzed
1002 ♀...	.7	7.4	+2.4	.5	4.7	+ .4	50	Paralyzed
1003 ♀...	.6	6.3	+1.8	.4	4.2	+ .2	49	Convulsive; died
989 ♀....	.5	5.1	+1.8	.4	4.1	+ .1	47	Humped, wobbly; died
			15 percent oats without autoclaved yeast					
925 ♂....	.6	4.2	+1.0	.5	3.5	+ .1	39	Convulsive
990 ♀....	.6	4.0	+1.1	.6	4.2	+ .1	264	Dead
			15 percent oats plus .4 gram autoclaved yeast daily					
870 ♂....	1.0	7.0	+3.0	.9	6.2	+ .5	85	Neuritic
871 ♂....	1.3	9.0	+2.9	.8	5.4	+ .4	88	Paralyzed
878 ♀....	1.2	8.3	+2.8	.9	6.0	+ .4	107	Slightly neuritic
879 ♀....	1.1	7.1	+2.1	.9	6.0	+ .8	107	Slightly neuritic
944 ♂....	.9	6.3	+2.7	.7	5.0	+ .6	58	Convulsive
945 ♂....	1.0	6.8	+2.7	.7	4.6	+ .3	58	Convulsive
926 ♀....	.8	5.3	+1.8	.8	5.4	+ .7	79	Convulsive
927 ♀....	1.0	6.6	+2.1	.9	6.2	+ .7	85	Convulsive
1007 ♀...	.9	6.0	+2.0	.6	4.3	+ .4	60	Paralyzed
1006 ♀...	.7	4.9	+1.6	.5	3.3	0	68	Paralyzed
991 ♀....	.8	5.4	+2.3	.7	4.6	+ .3	156	Dead
983 ♀....	.8	5.1	+1.7	.5	3.3	+ .3	79	Paralyzed
			25 percent oats without autoclaved yeast					
922 ♂....	1.3	5.1	+1.4	1.7	6.7	+ .5	268	Very pellagrous, slightly neuritic
998 ♀....	1.2	4.8	+1.3	1.6	6.5	+ .5	324	Pellagrous
			25 percent oats plus .4 gram autoclaved yeast daily					
946 ♀....	1.4	5.5	+2.4	2.0	7.8	+ .8	274	Neuritic, symptoms improved
947 ♂....	1.3	5.1	+2.6	1.3	5.0	+ .5	84	Paralyzed, dying
923 ♀....	1.4	5.7	+2.3	2.1	8.3	+1.4	108	Good
924 ♂....	1.5	6.0	+2.3	2.0	8.0	+1.1	205	Good
999 ♀....	1.7	6.7	+2.5	2.2	8.8	+1.2	162	Fur rough
1000 ♀...	1.2	4.9	+1.6	1.5	5.8	+1.1	110	Good
			25 percent sifted hulled oats					
1032 ♂...	1.5	6.1	+1.1	1.2	4.8	+ .5	136	Humped, pellagrous sores on mouth, priapism
1040 ♀...	1.5	6.1	+1.1	1.5	6.2	+ .6	95	Humped, brown fur on head
1048 ♀...	1.8	7.3	+ .8	1.3	5.1	+ .3	95	Humped, flabby muscles

TABLE 6.—*Concluded*

Rat No. and sex	During first twenty days: Average daily amount cereal	During first twenty days: Average daily food intake	During first twenty days: Average daily gain or loss in weight	During entire test period: Average daily amount cereal	During entire test period: Average daily food intake	During entire test period: Average daily gain or loss in weight	Test period	Condition at end of test
25 percent sifted Quaker oats plus .4 gram autoclaved yeast daily								
1031 ♂...	1.9	7.8	+2.5	2.5	10.1	+1.7	162	Good
1039 ♀...	2.0	8.0	+2.4	2.6	10.4	+1.2	154	Good
1047 ♂...	2.8	11.0	+2.6	2.4	9.7	+1.6	146	Good
25 percent Quaker oat groats								
1034 ♀...	.9	3.6	+1.0	1.0	4.1	+ .6	100	Pellagrous
1042 ♂...	1.0	3.9	+1.1	1.1	4.3	+ .3	166	Pellagrous, neuritic
1050 ♂...	1.1	4.4	+1.3	1.1	4.5	+ .6	95	Slightly pellagrous and slightly neuritic
25 percent Quaker oat groats plus .4 gram autoclaved yeast daily								
1033 ♂...	1.7	6.7	+3.4	2.1	8.6	+1.8	133	Flabby and neuritic
1041 ♀...	1.5	6.1	+2.1	1.8	7.2	+1.2	127	Good, except lids red
1049 ♂...	1.6	6.3	+2.5	1.9	7.7	+1.2	161	Good
25 percent Quaker oats without autoclaved yeast								
1036 ♂...	1.2	4.7	+1.5	1.3	5.2	+ .7	96	Slightly pellagrous, cessation of growth
1044 ♂...	1.0	4.1	+1.3	1.4	5.5	+ .7	166	Very pellagrous, mouth lesions
1052 ♀...	1.0	4.1	+1.1	1.0	4.1	+ .1	91	Very neuritic
25 percent Quaker oats plus .4 gram autoclaved yeast daily								
1035 ♀...	1.5	5.9	+2.4	1.9	7.6	+1.2	128	Humped
1043 ♂...	1.5	5.9	+2.1	1.7	6.9	+1.0	166	Rough and yellow
1051 ♀...	1.2	4.9	+1.9	1.5	5.9	+ .8	183	Good
25 percent Quick Quaker oats without autoclaved yeast								
1038 ♂...	1.0	3.8	+1.1	1.1	4.3	+ .4	96	Neuritic and pellagrous
1046 ♂...	1.4	5.4	+ .9	1.2	4.9	+ .3	91	Very neuritic
1054 ♂...	1.1	4.3	+ .8	1.1	4.4	+ .5	131	Very neuritic, very pellagrous
25 percent Quick Quaker oats plus .4 gram autoclaved yeast daily								
1037 ♂...	1.4	5.5	+2.8	1.8	7.4	+1.4	167	Good
1045 ♂...	1.7	6.8	+2.5	2.0	7.8	+1.4	166	Good
1053 ♂...	1.6	6.2	+2.6	1.7	6.9	+1.1	135	Good

meet the vitamin-B requirement for moderate but not optimum growth over an extended period of 100 days or more (Figs. 3 and 4).

The compiled data reveal some interesting facts concerning the food intake. In most cases when autoclaved yeast was given, the daily intake of food was increased over the amount ingested when the same food was fed without the autoclaved yeast. The increased growth of the animals receiving autoclaved yeast, however, was evidently not due to increased food intake alone. The variation among the different animals in each group as to daily food intake is such that rats with or without autoclaved yeast, eating comparable amounts of food, may be paired together, and the increased average daily gain of weight in

animals receiving the autoclaved yeast is still demonstrated. Particularly is this true during the first twenty days of the experiment. A selected example is presented in Table 7.

The growth of animals receiving the sifted hulled oats and the oat

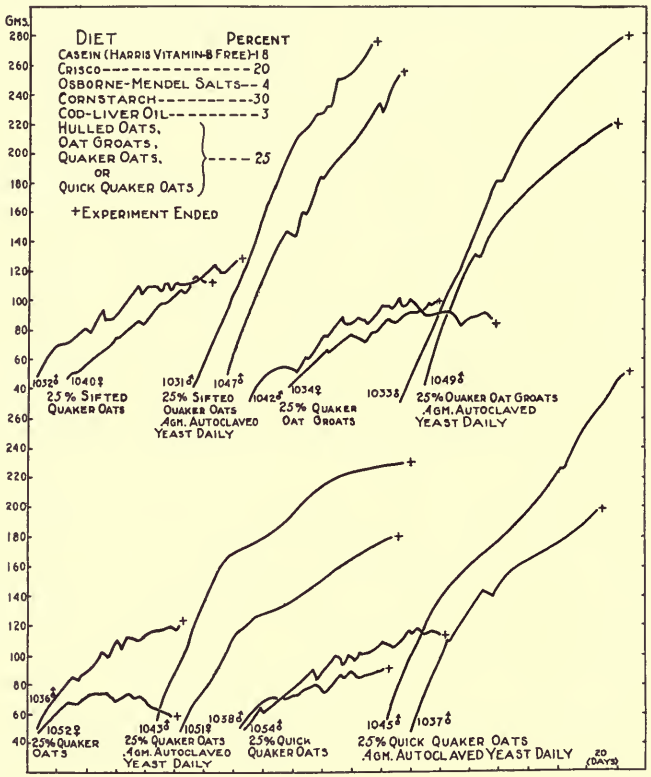

FIG. 4.—WEIGHT CURVES OF RATS RECEIVING (1) OATS PRODUCTS AS SOLE SOURCE OF VITAMINS B AND G; (2) OATS PRODUCTS AS SOLE SOURCE OF VITAMIN B WITH AUTOCLAVED YEAST FURNISHING VITAMIN G

Increased growth always resulted when autoclaved yeast supplemented the cereal product of the basal diet, which included Crisco and cornstarch.

products was approximately the same (Table 6). The large daily food intake of rats receiving sifted oats was probably due to the large amount of bran contained in this food.

Hunt[13]* in 1928 showed that wheat and corn are of equal value as sources of vitamins F (B) and G. He found that a diet consisting of 15 percent wheat, or 1 gram daily of wheat or corn, is the minimum amount necessary to supply sufficient vitamin F (B) for

growth. The results of experiments with wheat and corn (Tables 8 and 9, Fig. 5) confirm those of Hunt in regard to the increased growth induced in rats by the addition of autoclaved yeast (.4 gram daily) to diets in which these cereals are the sole source of vitamins B and G. On the other hand, these results differ from those of Hunt in respect to the amount of wheat or corn necessary to supply enough vitamin B

TABLE 7.—SELECTED EXAMPLE OF ANIMALS EATING VERY NEARLY SAME AVERAGE AMOUNT OF FOOD DAILY, THEIR DIETS DIFFERING ONLY IN THAT ONE RECEIVED AUTOCLAVED YEAST, A SOURCE OF VITAMIN G

	During first twenty days			During entire test period				
Rat No. and sex	Average daily amount cereal	Average daily food intake	Average daily gain or loss in weight	Average daily amount cereal	Average daily food intake	Average daily gain or loss in weight	Test period	Condition at end of test
10 percent oats without autoclaved yeast								
	gms.	*gms.*	*gms.*	*gms.*	*gms.*	*gms.*	*days*	
1001 ♀.....	.6	5.6	+1.1	.3	3.5	− .1	48	Dead
10 percent oats plus .4 gram autoclaved yeast daily								
943 ♀.....	.6	5.8	+2.2	.3	3.5	+ .2	53	Convulsive

for growth. Fifteen percent of wheat or corn in the diet was not found sufficient to prevent neuritis and death. When an amount as high as 25 percent of corn, or an average of 1.8 grams daily, was used as the sole source of vitamin B with the same otherwise adequate diet, only two of the rats grew at a rate approaching normal over a period of two months. Four other rats on this diet grew normally for a short period of about 20 days; later, growth ceased and varying degrees of neuritis developed. Two of these animals developed severe convulsions and were killed.

The University of Illinois experiment was carried on under conditions which differed only slightly from those of Hunt. Hunt used slightly older and larger rats. His basal diet differed only in the percentage of fats included. The latter difference may, however, be significant. In preliminary work done in the Home Economics laboratory of the University of Illinois a basal diet was used in which glucose replaced all the Crisco and cornstarch of the earlier diet. With only 15 percent corn or wheat as the sole source of vitamin B in this new diet, growth was obtained over a prolonged period of more than 150 days. In no cases were there more than slight indications of vitamin-B deficiency, but an optimum gain in weight was never attained. These results are presented in Table 10 and in the weight curves of Fig. 6.

The same difference in results between rats on the Crisco and corn-

TABLE 8.—EFFECT OF WHEAT AS SOURCE OF VITAMIN B IN DIET WHEN AUTOCLAVED YEAST WAS USED AS SOURCE OF VITAMIN G
(Crisco and cornstarch were used in diet)

Rat No. and sex	During first twenty days: Average daily amount cereal	Average daily food intake	Average daily gain or loss in weight	During entire test period: Average daily amount cereal	Average daily food intake	Average daily gain or loss in weight	Test period	Condition at end of test
15 percent whole wheat without autoclaved yeast								
	gms.	*gms.*	*gms.*	*gms.*	*gms.*	*gms.*	*days*	
916 ♀	.6	4.0	+ .4	.5	3.1	− .1	41	Neuritic
920 ♂	.7	4.5	+ .7	.6	3.7	+ .1	68	Convulsive
15 percent whole wheat plus .4 gram autoclaved yeast daily								
917 ♂	.9	6.2	+2.4	.7	4.5	+ .3	69	Convulsive
918 ♀	1.1	7.0	+2.3	.9	5.8	+1.0	45	Normal condition; killed
919 ♂	1.1	7.0	+2.4	.8	5.0	+ .6	65	Humped
921 ♂	1.1	7.5	+2.5	.9	6.0	+ .6	51	Priapism, humped; dead

TABLE 9.—EFFECTS OF VARYING LEVELS OF CORN AS SOURCES OF VITAMIN B IN DIET WHEN AUTOCLAVED YEAST WAS USED AS SOURCE OF VITAMIN G
(Crisco and cornstarch were used in diet)

Rat No. and sex	During first twenty days: Average daily amount cereal	Average daily food intake	Average daily gain or loss in weight	During entire test period: Average daily amount cereal	Average daily food intake	Average daily gain or loss in weight	Test period	Condition at end of test
15 percent whole yellow corn without autoclaved yeast								
	gms.	*gms.*	*gms.*	*gms.*	*gms.*	*gms.*	*days*	
905 ♂	1.0	6.4	+1.2	.9	5.7	0	43	Convulsive
909 ♀	.9	6.0	+1.0	.7	4.5	− .1	46	Neuritic; died
15 percent whole yellow corn plus .4 gram autoclaved yeast daily								
868 ♂	1.2	8.1	+2.8	.8	5.3	+ .1	45	Neuritic
869 ♀	1.0	7.0	+2.5	.9	5.7	+ .2	69	Convulsive
876 ♀	1.4	9.1	+2.4	.9	6.1	+ .3	48	Neuritic, paralyzed
877 ♀	1.2	8.3	+2.0	.9	6.1	+ .1	62	Convulsive
906 ♀	.9	6.2	+2.0	.6	4.3	+ .1	46	Convulsive
910 ♂	1.1	7.3	+2.6	.7	4.7	+ .1	54	Neuritic; died
911 ♂	1.0	7.0	+2.2	.8	5.3	+ .4	45	Neuritic, convulsive
25 percent whole yellow corn without autoclaved yeast								
903 ♂	1.6	6.6	+2.3	1.4	5.6	+ .6	90	Priapism, humped
907 ♂	1.5	5.9	+1.4	1.3	5.2	+ .5	51	Neuritic
25 percent whole yellow corn plus .4 gram autoclaved yeast daily								
867 ♂	1.9	7.7	+3.3	2.5	9.8	+2.7	76	Nervous, otherwise good
874 ♀	2.5	8.8	+3.0	2.4	9.5	+1.7	69	Nervous, otherwise good
875 ♂	1.5	6.1	+1.5	1.3	5.3	+ .1	62	Convulsive
904 ♂	1.5	6.1	+2.5	1.2	4.9	+ .4	54	Convulsive, priapism
908 ♀	2.0	8.0	+3.0	1.5	6.2	+ .7	87	Slightly neuritic
930 ♂	2.2	8.9	+2.9	2.1	8.3	+1.4	79	Slightly humped
931 ♂	1.8	7.1	+2.5	1.7	6.5	+ .9	79	Neuritic, flabby

starch basal diet and those on the glucose basal diet without fat (Crisco) was experienced in the case of oats as a source of vitamin B (Table 11, Fig. 7).

Animals receiving 10 or 25 percent oats as a source of vitamin B (autoclaved yeast used for vitamin G) grew as well with cornstarch

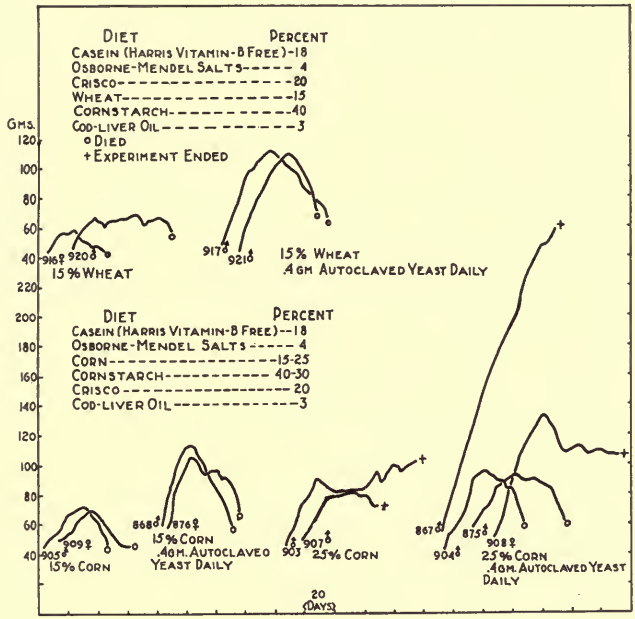

FIG. 5.—WEIGHT CURVES OF RATS RECEIVING (1) WHEAT OR CORN AS SOLE SOURCE OF VITAMINS B AND G; (2) WHEAT OR CORN AS SOLE SOURCE OF VITAMIN B WITH AUTOCLAVED YEAST FURNISHING VITAMIN G

Increased growth always resulted when .4 gram of autoclaved yeast supplemented the cereal of the basal diet, which included Crisco and cornstarch.

as with glucose in the basal diet (Table 12). The change in carbohydrate apparently did not affect the results when Crisco was not used.

Animals receiving either 15 percent corn, 15 percent wheat, or 15 or 25 percent oats as a source of vitamin B in a diet adequate in all respects (including autoclaved yeast for vitamin G) grew better when Crisco was not included in the diet. The average daily intake of food and hence of the cereal, as well as the average daily gains in weight, were comparable over the first twenty days of the test period for animals with and without Crisco. In the case of the group receiving the diet containing fat, a lowered food intake occurred after the twentieth day of the experiment, which resulted in a decrease in the amount of

cereal ingested and hence in vitamin B. This fact may account somewhat for the difference in total growth between animals in the two groups, but the loss in the appetites of the animals receiving the fat in the diet is not explainable. Apparently less of the food containing fat than of the food not containing fat is required to furnish the same

TABLE 10.—EFFECTS OF VARYING LEVELS OF CORN AND WHEAT AS SOURCES OF VITAMIN B IN DIET WHEN AUTOCLAVED YEAST WAS USED AS SOURCE OF VITAMIN G

(Glucose replaced Crisco and cornstarch of former diet; cod-liver oil was given separately)

Rat No. and sex	During first twenty days: Average daily amount cereal	Average daily food intake	Average daily gain or loss in weight	During entire test period: Average daily amount cereal	Average daily food intake	Average daily gain or loss in weight	Test period	Condition at end of test
Depletion on glucose basal diet, then 15 percent whole yellow corn without autoclaved yeast								
	gms.	*gms.*	*gms.*	*gms.*	*gms.*	*gms.*	*days*	
1143 ♀	.8	5.1	+ .4	.6	4.3	− .3	36	Paralyzed; died
1204 ♂	.5	3.7	− .5	.6	4.1	− .2	27	Anemic; died
1206 ♀	.5	3.2	− .2	.6	4.0	− .2	36	Yellow, oily, anemic; died
Depletion on glucose basal diet, then 15 percent whole yellow corn plus .4 gram autoclaved yeast daily								
1144 ♀	1.1	7.3	+2.4	1.0	6.9	+1.4	63	Good
1219 ♀	.8	5.5	+1.4	.8	5.2	+ .8	62	Good
Depletion on glucose basal diet, then 15 percent whole wheat without autoclaved yeast								
1135 ♀	.7	4.7	+ .7	.7	4.6	− .2	44	Neuritic
1146 ♂	.7	4.5	+ .6	.6	3.8	0	41	Neuritic
1154 ♀	.9	6.0	+ .7	.8	5.2	+ .3	127	Very neuritic, pellagrous; died
1203 ♂	.8	5.2	+ .3	.7	4.4	− .3	43	Humped; died
1216 ♂	.8	5.5	+ .7	.7	4.8	0	74	Convulsive; died
Depletion on glucose basal diet, then 15 percent whole wheat plus .4 gram autoclaved yeast daily								
1136 ♂[1]	1.0	6.9	+2.7	1.0	6.5	+1.1	63	Good
1220 ♂[1]	.8	5.1	+1.6	1.0	6.3	+1.6	61	Rough, humped, pale

[1]Rats 1136 ♂ and 1220 ♂ were maintained on the experiment for 219 and 145 days respectively. Both animals became slightly rough and growth became somewhat slower.

amount of energy. Since the energy requirement is recognized as an important guide to appetite, it is expected that a smaller amount of the fat food than of the fat-free food would be consumed. The food intake, and hence the absolute intake of cereal, was less in the cases where fat was included in the diet.

The difference in food intake apparently does not present an adequate explanation for the conflicting results obtained in testing for vitamin B when the basal diet contained Crisco and when it contained no other fat than cod-liver oil. Work is now in progress to repeat and perhaps explain these results.

In 1926 Smith and Hendrick[24]* found that when oats were used as the source of vitamin B in a diet composed of casein, inorganic salts, and fat-soluble vitamins, a material improvement in growth was experienced if autoclaved brewers' yeast was added. It is known now that

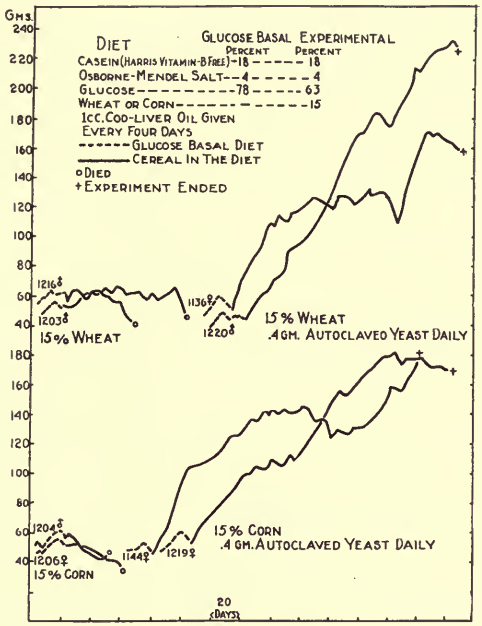

FIG. 6.—WEIGHT CURVES OF RATS RECEIVING WHEAT OR CORN AS SOURCE OF VITAMIN B WITH GLUCOSE REPLACING CRISCO AND CORNSTARCH

When autoclaved yeast was given along with this diet, in which Crisco and cornstarch were replaced by glucose, appreciably better growth occurred on a given percentage of the cereal than occurred on the same percentage of cereal in the former diet.

the autoclaved yeast supplied vitamin G to the diet, and that oats are deficient in this vitamin. The work here presented confirms the work of Smith and Hendrick and extends the data to include the results of a quantitative study of the vitamin-B value of oats.

Oats, according to the data presented, contain a slightly higher amount of vitamin B than does wheat or corn. During the entire test period the animals receiving the same percentage of each of these three cereals plus autoclaved yeast, grew at approximately the same rate, but the condition of the animals receiving oats was invariably better than that of the animals receiving corresponding levels of the other two cereals. This fact is especially emphasized by the results in the cases

TABLE 11.—EFFECTS OF VARYING LEVELS OF OATS AS SOURCES OF VITAMIN B IN DIET WHEN AUTOCLAVED YEAST WAS USED AS SOURCE OF VITAMIN G

(Glucose replaced Crisco and cornstarch of former diet; cod-liver oil was given separately)

Rat No. and sex	During first twenty days: Average daily amount cereal	During first twenty days: Average daily food intake	During first twenty days: Average daily gain or loss in weight	During entire test period: Average daily amount cereal	During entire test period: Average daily food intake	During entire test period: Average daily gain or loss in weight	Test period	Condition at end of test
Depletion on glucose basal diet, then 15 percent oats without autoclaved yeast								
	gms.	*gms.*	*gms.*	*gms.*	*gms.*	*gms.*	*days*	
1151 ♀	.9	5.9	+1.2	1.2	7.9	+ .7	183	Yellow, rough, humped
1202 ♀	1.0	6.5	+1.3	.7	4.9	0	141	Dead
1215 ♀	.8	5.2	+1.8	.8	5.1	−1.2	156	Neuritic
Depletion on glucose basal diet, then 15 percent oats and .4 gram autoclaved yeast daily								
1152 ♀	1.3	8.6	+3.4	1.4	9.3	+2.2	59	Good
1205 ♂	1.8	12.1	+3.9	1.5	9.8	+2.7	61	Slightly yellow, good
1218 ♀	1.1	7.5	+3.1	1.2	8.5	+2.1	61	Good
25 percent oats without autoclaved yeast without depletion								
1061 ♀	1.5	5.9	+1.6	1.3	8.5	+ .6	224	Pellagrous
1067 ♂	1.9	7.7	+1.3	2.7	10.8	+1.0	222	Slightly yellow and rough
25 percent oats plus .4 gram autoclaved yeast daily without depletion								
1060 ♂	2.0	8.0	+2.9	2.8	11.2	+2.0	110	Yellow, coarse fur
1066 ♀	1.7	6.6	+2.6	2.3	9.2	+1.6	108	Good
Depletion on glucose basal diet, then 50 percent oats without autoclaved yeast								
1175 ♂	5.0	9.9	+3.8	6.4	12.8	+2.0	87	Slightly rough fur, otherwise good
1176 ♂	4.7	9.4	+4.4	6.8	13.7	+2.7	87	Good
1310 ♂	3.8	7.6	+4.7	5.2	10.4	+2.4	88	Developed rattles
1460 ♀	3.9	7.8	+2.4	5.1	10.3	+1.4	88	Good, tail brown
1461 ♂	3.1	6.3	+2.0	4.3	8.6	+1.5	88	Rough, yellow
1462 ♂	3.8	7.6	+2.5	4.6	9.3	+1.3	88	Good
Depletion on glucose basal diet, then 50 percent oats plus .4 gram autoclaved yeast daily								
1307 ♂	5.0	9.9	+5.6	5.3	10.7	+2.9	88	Good, tho slightly rough fur
1463 ♀	4.4	8.8	+3.7	5.6	11.2	+2.1	88	Good, tho slightly rough and yellow
1464 ♂	4.5	9.0	+3.5	6.7	13.4	+2.5	88	Good, tho rough and yellow
1465 ♀	3.7	7.6	+3.7	5.7	11.4	+1.7	88	Good, tho rough and yellow

where the diets consisted of 25 percent or more of oats or corn; only two oats-fed rats developed neuritis, while all the animals receiving 25 percent corn with Crisco and cornstarch showed symptoms characteristic of vitamin-B deficiency. All animals that received a diet made up of 15 percent or less of the cereals, whether supplemented with auto-

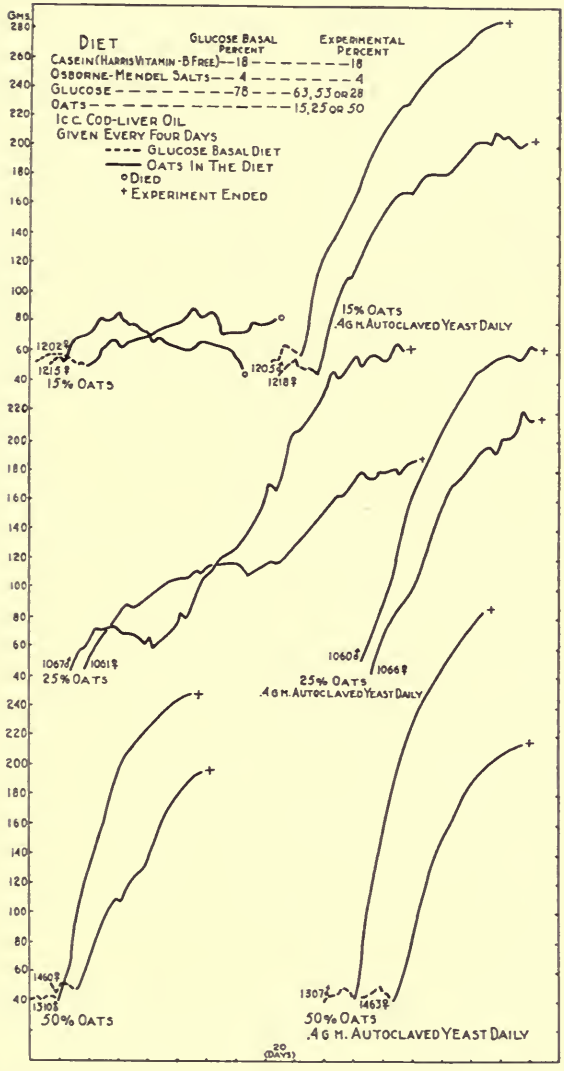

FIG. 7.—WEIGHT CURVES OF RATS RECEIVING OATS AS SOURCE OF VITAMIN B WITH GLUCOSE REPLACING CRISCO AND CORNSTARCH

When .4 gram of autoclaved yeast was fed daily along with an oats diet in which Crisco and cornstarch were replaced by glucose, appreciably better growth occurred on a given percentage of the oats than occurred on the same percentage in the former diet.

claved yeast or not, developed neuritic symptoms and usually died in a convulsive or paralyzed condition.

TABLE 12.—EFFECTS OF VARYING LEVELS OF OATS AS SOURCES OF VITAMIN B IN DIET WHEN CORNSTARCH REPLACED CRISCO OF THE BASAL DIET AND AUTOCLAVED YEAST SUPPLIED VITAMIN G

Rat No. and sex	During first twenty days: Average daily amount cereal	During first twenty days: Average daily food intake	During first twenty days: Average daily gain or loss in weight	During entire test period: Average daily amount cereal	During entire test period: Average daily food intake	During entire test period: Average daily gain or loss in weight	Test period	Condition at end of test
	gms.	*gms.*	*gms.*	*gms.*	*gms.*	*gms.*	*days*	
10 percent oats and 10 percent autoclaved yeast								
1544 ♀	.8	7.6	+2.6	.8	7.7	+1.5	56	Good
1564 ♀	.7	7.4	+2.3	.6	6.4	+1.0	56	Thin
25 percent oats and 10 percent autoclaved yeast								
1525 ♀	2.2	8.9	+3.5	2.6	10.5	+2.1	72	Good
1527 ♀	1.6	6.2	+2.5	2.5	10.0	+2.0	72	Good
1529 ♀	1.8	7.1	+2.1	2.3	9.1	+1.9	72	Good
1532 ♀	2.0	8.1	+3.2	2.5	10.1	+2.1	70	Good
1550 ♀	1.9	7.8	+3.3	2.3	9.1	+1.7	69	Good

All animals fed a diet consisting of 25 percent oats without autoclaved yeast became somewhat neuritic. They also developed from time to time pellagra-like lesions around the mouth, fore digits, and tail. The fur became short, woolly, and, in several cases, extremely yellow or brown. Animals receiving 50 percent oats, corn, or wheat, without autoclaved yeast, grew at an approximately normal rate.

In the case of oats, observations were made on animals receiving autoclaved yeast along with 50 percent of this cereal. When the same amount of food, either with or without autoclaved yeast, was ingested, better growth and nutritive condition occurred in those cases in which the oats were supplemented with vitamin G (Table 11, Fig. 7). Altho no such experiments have been tried with wheat or corn, it is probable that autoclaved yeast added to these also, would stimulate growth and improve the nutritive condition of the animals.

III. VITAMIN-G CONTENT OF WHOLE, HULL-LESS OATS, WHOLE YELLOW CORN, WHOLE WINTER WHEAT, AND RICE POLISHINGS

In testing the vitamin-G content of whole hull-less oats, whole yellow corn, whole winter wheat, and rice polishings, a basal diet was used containing glucose as a source of carbohydrate and no fat other than cod-liver oil to supply vitamins A and D.

	perct.
Casein (Harris, free from water-soluble vitamin B)	18
Osborne-Mendel salt mixture	4
Glucose, C. P. (or later glucose and cereal)	78
Cod-liver oil, 1 cc. every 4 days	

Young rats, it was found, could adjust themselves to this purified diet and grow normally if sufficient amounts of dried or autoclaved brewers' yeast and tikitiki were given as a source of vitamins B and G. When these vitamins were not supplied, the animals became extremely neuritic, lost weight, and died at about the thirtieth day after the test period began.

Sharper and more definite responses to vitamin G were obtained if the animal was depleted of vitamin G in a period preliminary to the adding of the test material to the diet (Fig. 8). A procedure similar to that used by Chick and Roscoe[4]* was adopted.

Tikitiki, an alcoholic extract of rice polishings, reported by Evans and Burr[10]* to be a potent source of vitamin B and low in vitamin G was withheld for economic purposes until symptoms of vitamin-B depletion appeared. These symptoms usually occurred about two weeks after the depletion period began. At this time the tikitiki was given separately in daily doses. Various amounts of the tikitiki were used in an attempt to find an amount which would supply enough vitamin B for satisfactory growth. Response in growth invariably occurred when tikitiki was fed, accompanied by a cessation of neuritic symptoms. When the animals ceased growing or declined in weight, the vitamin-G test was begun. In cases where the cereal was fed at a low level, that is, where it made up only 15 percent of the diet, untreated cereal was always used. When it made up 25 to 50 percent of the diet, it was fed both untreated and autoclaved. The test material was autoclaved in the same manner as has been described for the preparation of autoclaved or vitamin-B-free yeast. This freeing of test material from vitamin B is contrary to the practice of Chick and Roscoe,[4]* who state: "It is not necessary for the test material to be freed from vitamin B_1 of which an excess is already present in the diet." The procedure was adopted here, however, in order to control the amount of vitamin B furnished to each animal.

If fed at a high enough level, cereals can furnish enough vitamin G for approximately normal growth in the rat (Tables 13 to 16, Figs. 8 to 12). Animals receiving tikitiki in amounts of 1 to 12 drops daily, as a source of vitamins B and G in a diet otherwise free from these vitamins, always showed an improvement in nutritive condition and growth when either untreated or autoclaved oats, wheat, corn, or yeast, or autoclaved rice polishings were added to the diet. Considerably better growth occurred when a diet containing 50 percent autoclaved cereal was fed than when 25 percent of the same autoclaved cereal was used. Animals receiving less than 3 drops of tikitiki daily, as the

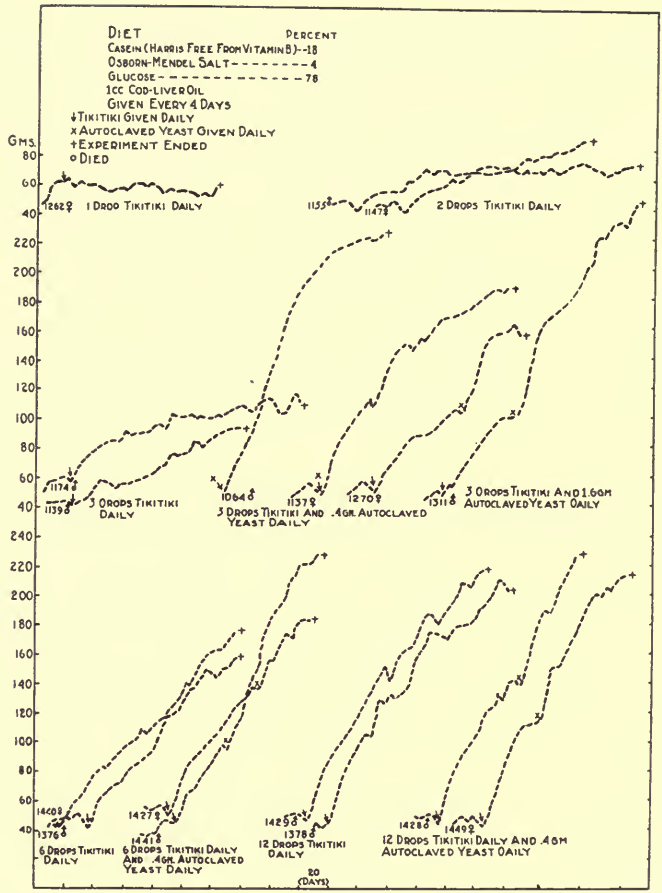

FIG. 8.—WEIGHT CURVES OF RATS RECEIVING (1) TIKITIKI AS SOLE SOURCE OF VITAMINS B AND G; (2) TIKITIKI AS SOLE SOURCE OF VITAMIN B WITH AUTOCLAVED YEAST FURNISHING VITAMIN G

Good growth was obtained when 6 or 12 drops daily of tikitiki were used as the sole source of vitamins B and G in the diet. Improved growth always resulted when autoclaved yeast was given along with the tikitiki.

sole source of vitamins B and G, developed neuritic symptoms which were not alleviated even when autoclaved cereal to the extent of 50 percent of the diet was fed. Six or 12 drops of tikitiki daily, in addition to a diet otherwise free from vitamins B and G, produced growth somewhat below normal. The growth thus produced was stimulated either by the inclusion in the diet of 25 or 50 percent autoclaved oats, wheat, or corn, or by the addition of autoclaved yeast. The stimula-

TABLE 13.—EFFECT OF TIKITIKI ON GROWTH AND CONDITION OF VITAMIN-B DEPLETED RATS WHEN (1) AUTOCLAVED YEAST WAS USED AS SOURCE OF VITAMIN G, (2) WHEN NO AUTOCLAVED YEAST WAS GIVEN

(Calculations for the second group were based on a period begun 60 days after the tikitiki was first given, a time comparable to that at which autoclaved yeast was given to the first group)

Rat No. and sex	During first twenty days: Daily amount tikitiki	Daily amount autoclaved yeast	Average daily food intake	Average daily gain or loss in weight	During entire test period: Daily amount tikitiki	Daily amount autoclaved yeast	Average daily food intake	Average daily gain or loss in weight	Test period	Condition at end of test
Depletion on "glucose basal" diet, then tikitiki, then autoclaved yeast daily										
	drops	*gms.*	*gms.*	*gms.*	*drops*	*gms.*	*gms.*	*gms.*	*days*	
1137 ♀.....	3	.4	6.4	+2.6	3	.4	8.2	+1.1	127	Good
1138 ♀[1].....	3	.4	5.6	+1.3	3	.4	8.3	+1.2	99	Good
1270 ♀.....	3	.4	10.1	+2.7	3	.4	7.7	+1.2	48	Slightly rough
1309 ♀.....	3	.4	7.7	+2.0	3	.4	7.4	+1.3	42	Rough
1311 ♂.....	3	1.6	11.2	+3.5	3	1.6	10.7	+1.9	77	Good
1313 ♂.....	3	1.6	10.0	+1.9	3	1.6	9.6	+1.7	63	Humped, rough
1427 ♀.....	6	.4	11.1	+1.8	6	.4	10.5	+1.0	56	Slightly rough, tail bad
1441 ♂.....	6	.4	12.5	+2.8	6	.4	11.8	+2.0	63	Rough, scaly tail
1428 ♂.....	12	.4	12.4	+2.4	12	.4	12.2	+2.4	36	Rough, quite good
1449 ♀.....	12	.4	8.8	+2.0	12	.4	10.8	+1.7	60	Slightly rough, ringed tail
Depletion on "glucose basal" diet with the later addition of tikitiki										
1262 ♀.....	1	..	4.6	− .2	1	..	3.8	0	48	Tail scaly, yellow, oily, neuritic; killed
1147 ♀.....	2	..	5.1	− .1	2	..	5.2	0	115	Rough, small, woolly fur; killed
1155 ♂.....	2	..	4.9	+ .3	2	..	5.6	+ .2	194	Pellagrous, priapism; killed
1139 ♂[2].....	3	..	5.5	+1.0	3	..	6.9	+ .4	56	Fur woolly
1174 ♂[2].....	3	..	6.9	+ .5	3	..	6.5	+ .2	90	Fur woolly, nervous, scaly tail and feet
1376 ♂.....	6	..	6.6	+1.6	6	..	8.6	+ .8	68	Woolly, humped, swollen jaws
1440 ♀.....	6	..	6.0	+1.5	6	..	11.9	+ .8	54	Rough, scaly tail
1471 ♀.....	6	..	5.8	+2.0	6	..	7.2	+ .7	47	Woolly, small, humped
1378 ♂.....	12	..	6.9	+2.0	12	..	11.0	+ .9	36	Woolly
1429 ♂.....	12	..	7.5	+2.5	12	..	10.4	+ .9	67	Woolly and humped, swollen jaws
1472 ♂.....	12	..	6.0	+2.3	12	..	9.1	+ .8	47	Flabby, tail rough

[1]Tikitiki and autoclaved yeast given simultaneously after depletion. [2]1139 ♂ and 1174 ♂ were kept on the diet for 100 and 138 days respectively with little if any change in growth or condition.

TABLE 14.—EFFECTS OF VARYING LEVELS OF UNTREATED OR AUTOCLAVED WHOLE HULL-LESS OATS ON GROWTH AND GENERAL CONDITION OF VITAMIN-G DEFICIENT RATS, VITAMIN B FURNISHED BY TIKITIKI

	During first twenty days				During entire test period				
Rat. No. and sex	Daily amount tikitiki	Average daily amount cereal	Average daily food intake	Average daily gain or loss in weight	Average daily amount cereal	Average daily food intake	Average daily gain or loss in weight	Test period	Condition at end of test
				Depletion, then tikitiki and 15 percent oats					
	drops	*gms.*	*gms.*	*gms.*	*gms.*	*gms.*	*gms.*	*days*	
1265 ♂.....	3	1.6	10.5	+1.8	1.2	7.9	+1.2	96	Good, slightly yellow, rough
				Depletion with tikitiki, then 25 percent oats					
1476 ♀.....	3	2.4	9.8	+3.4	3.1	12.5	+2.0	60	Good
1477 ♂.....	3	2.2	8.6	+2.7	2.9	11.7	+2.5	56	Good
				Depletion with tikitiki, then 25 percent autoclaved oats					
1259 ♀.....	3	1.7	6.6	+1.5	1.8	6.9	+ .8	71	Good
1264 ♂.....	3	1.7	6.9	+2.0	1.9	7.5	+ .2	72	Brown head, rough
1474 ♂.....	3	1.6	6.6	+ .8	1.5	6.1	+ .8	60	Woolly, humped, thin
1269 ♀.....	6	2.3	9.0	+1.0	2.4	9.4	+ .8	62	Stiff, ugly, yellow fur, eye sore
1411 ♂.....	6	4.1	16.5	+1.4	2.7	10.8	+2.6	44	Woolly, yellow
1430 ♂.....	6	3.0	11.8	+2.6	3.0	11.8	+2.4	40	Humped, fur rough
1370 ♂.....	12	3.5	14.0	+3.2	3.8	14.5	+2.2	44	Rough, stiff fur, good
1419 ♀.....	12	2.3	9.4	+1.3	2.2	8.8	+1.7	44	Good
1434 ♀.....	12	2.8	11.3	+1.7	2.8	11.2	+1.6	30	Good
				Depletion, then tikitiki and 50 percent oats					
1308 ♂.....	3	4.7	9.4	+4.3	5.6	11.1	+2.4	80	Slightly rough, dark tail
1466 ♂.....	3	4.6	9.3	+4.2	6.0	12.0	+2.2	84	Slightly rough
1469 ♂.....	3	5.8	11.6	+3.7	4.6	9.2	+1.5	94	Thin, nervous
1470 ♂.....	3	3.1	6.2	+3.3	5.3	10.5	+2.3	88	Rough, fur stiff and coarse
1475 ♀.....	3	3.9	7.9	+2.9	5.9	11.8	+1.8	86	Humped, rough, yellow

TABLE 14.—*Concluded*

Rat No. and sex	During first twenty days: Daily amount tikitiki	Average daily amount cereal	Average daily food intake	Average daily gain or loss in weight	During entire test period: Average daily amount cereal	Average daily food intake	Average daily gain or loss in weight	Test period	Condition at end of test
Depletion with tikitiki, then 50 percent autoclaved oats									
	drops	*gms.*	*gms.*	*gms.*	*gms.*	*gms.*	*gms.*	*days*	
1134 ♂.....	1	3.5	7.1	+1.5	2.4	4.7	+ .4	79	Nervous, humped
1159 ♀.....	1	1.3	2.6	+ .2	3.0	6.1	+ .2	147	Pale, weak, humped
1167 ♂.....	1	1.9	3.8	+1.2	2.1	4.2	+ .1	76	Convulsive; died
1142 ♀.....	2	2.6	5.1	+1.0	2.3	4.5	+ .3	95	Slightly humped, white
1160 ♀.....	2	2.5	5.1	+1.2	3.3	6.6	+ .4	135	Humped, nervous
1168 ♂.....	2	3.4	6.8	+2.0	3.7	7.4	+ .8	171	White, rough
1210 ♀.....	2	3.3	6.5	+1.6	2.9	5.9	+ .5	110	Good
1150 ♂[1].....	3	4.1	8.2	+3.9	4.0	8.0	+1.3	91	Good
1166 ♂[1].....	3	4.7	9.4	+2.8	4.9	9.8	+1.4	91	Slightly oily, slightly yellow, brown head
1371 ♂.....	6	7.8	15.6	+3.0	7.0	14.0	+2.3	40	Good, except nose hemorrhage
1372 ♂.....	6	8.9	17.8	+4.3	6.9	13.9	+3.2	32	Slightly rough, brown fur
1413 ♀.....	6	5.7	11.5	+3.4	5.8	11.5	+2.2	48	Fur slightly rough, sore on head
1415 ♀.....	6	6.5	13.0	+2.8	5.5	11.1	+1.7	48	Fur slightly rough, good
1473 ♀.....	6	5.1	10.2	+3.1	5.7	11.3	+1.6	48	Good
1368 ♂.....	12	8.3	16.5	+4.2	7.9	15.8	+3.8	32	Slightly rough, tail scaly
1369 ♂.....	12	7.3	14.6	+3.2	7.5	15.0	+3.1	24	Rough
1423 ♀.....	12	6.4	12.8	+1.1	6.1	12.2	+1.1	34	Rough
1437 ♀.....	12	8.4	16.8	+2.7	6.4	12.8	+1.8	40	Rough

[1]1150 ♂ and 1166 ♂ were maintained on the experimental diet for over 100 days with no great difference in results from those given for 90 days.

TABLE 15.—EFFECTS OF VARYING LEVELS OF UNTREATED OR AUTOCLAVED WHOLE WINTER WHEAT AND OF RICE POLISHINGS ON GROWTH AND GENERAL CONDITION OF VITAMIN-G DEFICIENT RATS, VITAMIN B FURNISHED BY TIKITIKI

Rat No. and sex	During first twenty days: Daily amount tikitiki	Average daily amount cereal	Average daily food intake	Average daily gain or loss in weight	During entire test period: Average daily amount cereal	Average daily food intake	Average daily gain or loss in weight	Test period	Condition at end of test
Depletion, then tikitiki and 15 percent whole wheat									
	drops	*gms.*	*gms.*	*gms.*	*gms.*	*gms.*	*gms.*	*days*	
1281 ♀.....	3	.9	6.2	+1.5	1.3	8.4	+1.0	96	Yellow, rough
Depletion with tikitiki, then 25 percent whole wheat									
1479 ♀.....	3	1.9	7.7	+1.5	2.6	10.6	+1.5	56	Good, dark tail
1478 ♀.....	3	2.1	8.4	+1.3	2.5	10.0	+1.4	48	Thin, humped, nervous
Depletion with tikitiki, then 25 percent autoclaved wheat									
1263 ♀.....	3	1.6	6.4	+1.9	1.8	7.1	+1.2	80	Good
1278 ♀.....	3	2.1	8.4	+2.2	2.0	8.0	+1.0	44	Good
1285 ♀.....	3	1.8	7.3	+ .9	1.7	6.7	+ .8	66	Slightly rough, yellow
1416 ♀.....	6	2.6	10.2	+1.9	2.5	9.9	+1.8	48	Rough, sore tail
1432 ♂.....	6	2.5	9.9	+2.5	3.0	12.2	+1.7	44	Woolly, humped
1444 ♂.....	6	3.2	12.6	+3.1	3.1	12.3	+2.0	56	Good, rough
1424 ♀.....	12	2.8	11.2	+2.0	3.2	12.7	+1.3	52	Good, dark tail, brown head
1445 ♂.....	12	3.3	13.4	+2.6	3.4	13.5	+1.9	28	Slightly rough, yellow, dark tail
Depletion with tikitiki, then 50 percent autoclaved wheat									
1132 ♂.....	1	2.1	4.2	+1.4	2.4	4.9	+ .2	67	Paralyzed, priapism
1208 ♂.....	1	2.3	4.6	+1.1	2.1	4.1	+ .2	122	Pale, humped, priapism
1211 ♂.....	2	3.1	6.2	+1.5	3.0	6.0	+ .6	110	Good
1140 ♂.....	2	3.4	6.8	+1.5	2.1	4.2	+ .5	170	Slightly yellow, rough, humped
1148 ♂[1].....	3	3.8	7.7	+3.1	4.0	7.9	+1.3	91	Good
1213 ♂[1].....	3	3.8	7.6	+2.3	5.0	10.0	+1.2	92	Good
1418 ♂.....	6	5.8	11.6	+3.7	5.6	11.3	+2.6	32	Slightly rough
1421 ♂.....	6	7.0	14.0	+3.5	6.9	13.9	+2.8	28	Slightly rough, yellow
1426 ♂.....	12	6.9	13.8	+4.0	6.5	13.1	+2.9	36	Scaly tail, rough fur
1439 ♂.....	12	7.7	15.3	+4.4	7.8	15.6	+2.9	48	Rough, brown tail
1448 ♀.....	12	5.7	11.3	+ .7	6.7	13.4	+1.5	46	Slightly rough, nervous
Depletion with tikitiki, then 50 percent autoclaved rice polishings									
1373 ♂.....	3	4.8	9.6	+2.7	4.4	8.8	+1.6	44	Very pellagrous
1375 ♂.....	3	4.8	9.6	+3.0	4.8	9.5	+2.2	44	Pellagrous, scaly tail

[1]1148 ♂ and 1213 ♂ were maintained on the experimental diet over a period of 110 to 140 days with little if any change in growth or condition after the 90th day.

TABLE 16.—EFFECTS OF VARYING LEVELS OF UNTREATED OR AUTOCLAVED WHOLE YELLOW CORN ON GROWTH AND GENERAL CONDITION OF VITAMIN-G DEFICIENT RATS, VITAMIN B FURNISHED BY TIKITIKI

Rat No. and sex	During first twenty days: Daily amount tikitiki	Average daily amount cereal	Average daily food intake	Average daily gain or loss in weight	During entire test period: Average daily amount cereal	Average daily food intake	Average daily gain or loss in weight	Test period	Condition at end of test
Depletion, then tikitiki and 15 percent corn									
	drops	*gms.*	*gms.*	*gms.*	*gms.*	*gms.*	*gms.*	*days*	
1279 ♀.....	3	.9	6.2	+1.1	1.1	7.5	+1.0	116	Slightly rough
1280 ♀.....	3	1.3	8.7	+2.0	1.4	9.5	+1.3	100	Yellow but good
Depletion with tikitiki, then 25 percent corn									
1481 ♀.....	3	1.7	6.7	+2.6	2.7	10.9	+1.8	52	Slightly rough
1480 ♀.....	3	2.8	11.3	+2.4	3.2	12.9	+2.1	52	Good
Depletion with tikitiki, then 25 percent autoclaved corn									
1260 ♀.....	3	1.7	6.6	+ .6	1.4	5.7	+ .5	44	Very pellagrous
1282 ♀.....	3	1.9	7.8	+1.0	1.8	7.2	+ .5	44	Rough and humped
1284 ♀.....	3	1.7	6.6	+ .6	1.8	7.2	+ .3	44	Rough and nervous
1412 ♀.....	6	2.3	9.4	+2.0	2.9	11.6	+2.2	52	Good
1431 ♂.....	6	2.1	8.2	+2.0	2.9	11.7	+1.9	44	Woolly, yellow, humped, priapism
1443 ♀.....	6	3.1	12.5	+2.2	3.1	12.4	+2.3	30	Good, slightly rough
1420 ♀.....	12	2.6	10.5	+1.5	2.7	10.9	+1.0	36	Slightly rough
1422 ♀.....	12	3.1	12.2	+2.1	3.1	12.3	+1.5	36	Good
1435 ♀.....	12	3.0	12.1	+1.2	3.6	14.3	+1.1	30	Rough, scaly tail
1442 ♂.....	12	3.5	13.9	+3.1	3.4	13.5	+2.7	32	Good except tail brown
Depletion with tikitiki, then 50 percent autoclaved corn									
1133 ♂.....	1	2.1	4.1	+ .7	1.8	3.7	+ .1	35	Twisting, paralyzed
1209 ♀.....	1	2.0	3.9	+ .1	2.1	4.2	+ .2	60	Neuritic; died
1212 ♀.....	2	3.8	7.5	+ .6	4.2	8.4	+ .5	110	Slightly humped, good
1141 ♀.....	2	3.7	7.3	+ .9	2.9	5.8	+ .2	96	Fur off, humped, nervous
1149 ♂[1].....	3	3.6	7.2	+1.8	3.6	7.2	+1.1	91	Good
1214 ♀[1].....	3	3.9	7.7	+2.1	4.5	9.0	+ .6	92	Slightly rough, slightly humped
1417 ♂.....	6	3.8	7.6	+2.8	4.4	8.7	+1.9	48	Slightly rough
1433 ♂.....	6	5.9	11.8	+3.4	7.0	14.0	+2.4	52	Good
1447 ♂.....	6	5.6	11.2	+3.4	7.4	14.8	+2.7	40	Yellow, rough
1425 ♀.....	12	6.4	12.7	+2.1	6.0	12.1	+1.1	56	Slightly rough, brown fur
1438 ♂.....	12	7.9	15.8	+4.8	7.8	15.6	+4.1	28	Good
1446 ♂.....	12	7.6	15.2	+4.5	7.5	15.1	+2.9	56	Rough, yellow

[1]1149 ♂ and 1214 ♀ were maintained on the experiment for 143 and 110 days respectively with the result that growth almost completely ceased after the 90th day.

tion of growth was much more marked when these autoclaved foods were given along with the 3 drops of tikitiki daily than when the larger amounts of tikitiki were used.

The food consumption of animals that received cereal along with tikitiki in the diet was usually greater than that of animals that received only tikitiki for vitamins B and G (Tables 13 to 16). In the cases of control animals that received the tikitiki alone, the food intake increased when more tikitiki was given, or after the first twenty days of the experiment, when the animals were older and somewhat larger. The average daily food consumption of the control animals receiving autoclaved yeast and tikitiki and of the comparable experimental animals receiving autoclaved cereals and tikitiki was about the same, both during the first twenty days of the experiment and over the entire experimental period. Where the larger amounts of tikitiki were given daily along with the cereal, the food intake of animals receiving 12 drops of tikitiki was only slightly more than that of animals receiving 6 drops, and the average daily gain in weight was very similar. The animals receiving 3 drops of tikitiki daily and 25 or 50 percent autoclaved cereal, however, ingested considerably less food and grew at a slower rate than the animals with diets that differed only by the inclusion of larger amounts of tikitiki.

Considerably better growth was obtained when the diet included 25 percent untreated cereal with 3 drops of tikitiki daily than when the same amount of autoclaved cereal was given with 3 drops of tikitiki. Marked increase in food intake accompanied the use of untreated cereal, and for this reason it was difficult to determine whether increased growth was due to the larger intake of food, to the fact that more vitamin B was included in the diet, or to the fact that more vitamin G may be present in untreated than in autoclaved cereal. The use of autoclaved cereal eliminated the factors of increased ingestion of food and the inclusion of increased vitamin B in the diet since the appetites did not increase appreciably when autoclaved cereal free from vitamin B was given along with tikitiki.

Animals whose diets consisted of 50 percent untreated oats and 3 drops of tikitiki daily grew at about the same rate as animals receiving 50 percent of oats without tikitiki, and somewhat better than animals receiving the same amount of tikitiki with 50 percent autoclaved oats. The animals receiving the autoclaved cereal, however, ingested a somewhat lower amount of food over the entire experimental period and exhibited outwardly a somewhat better nutritive condition than did animals whose diets differed only in that untreated cereal was used. It

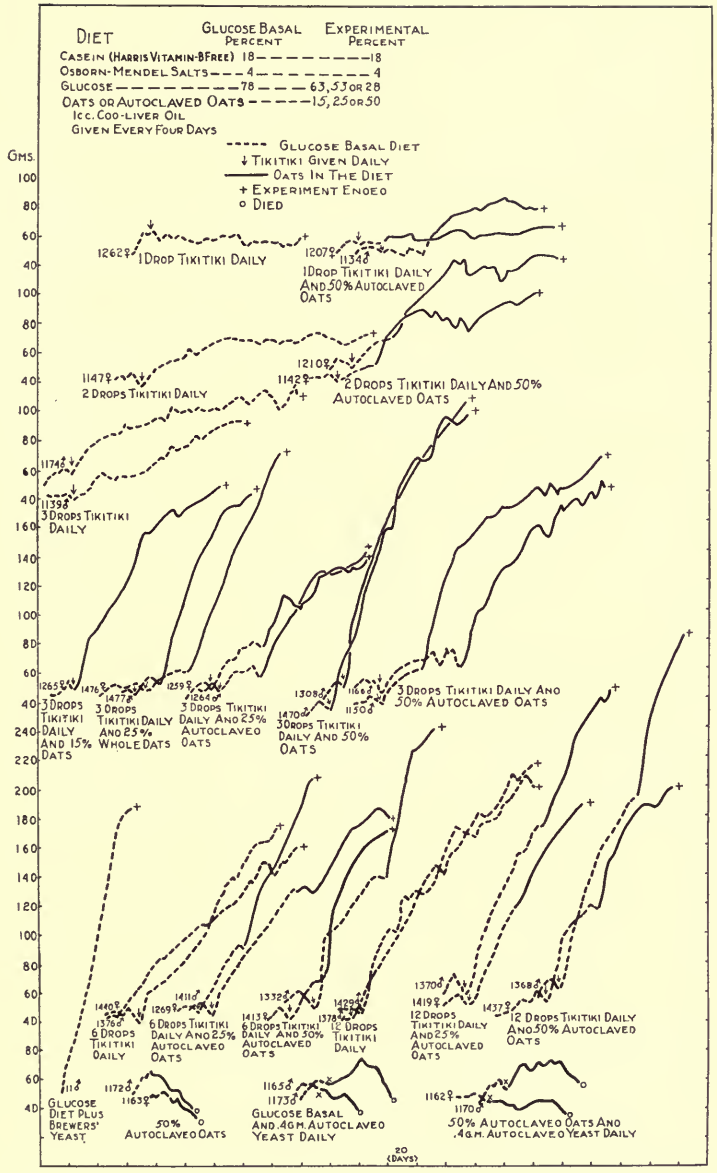

FIG. 9.—WEIGHT CURVES OF RATS RECEIVING UNTREATED OR AUTOCLAVED OATS AS SOURCE OF VITAMIN G WITH TIKITIKI AS SOURCE OF VITAMIN B

Good growth was obtained when 6 or 12 drops of tikitiki were used daily as the sole source of vitamins B and G in the diet. Improved growth always occurred when untreated or autoclaved oats were added to the diet.

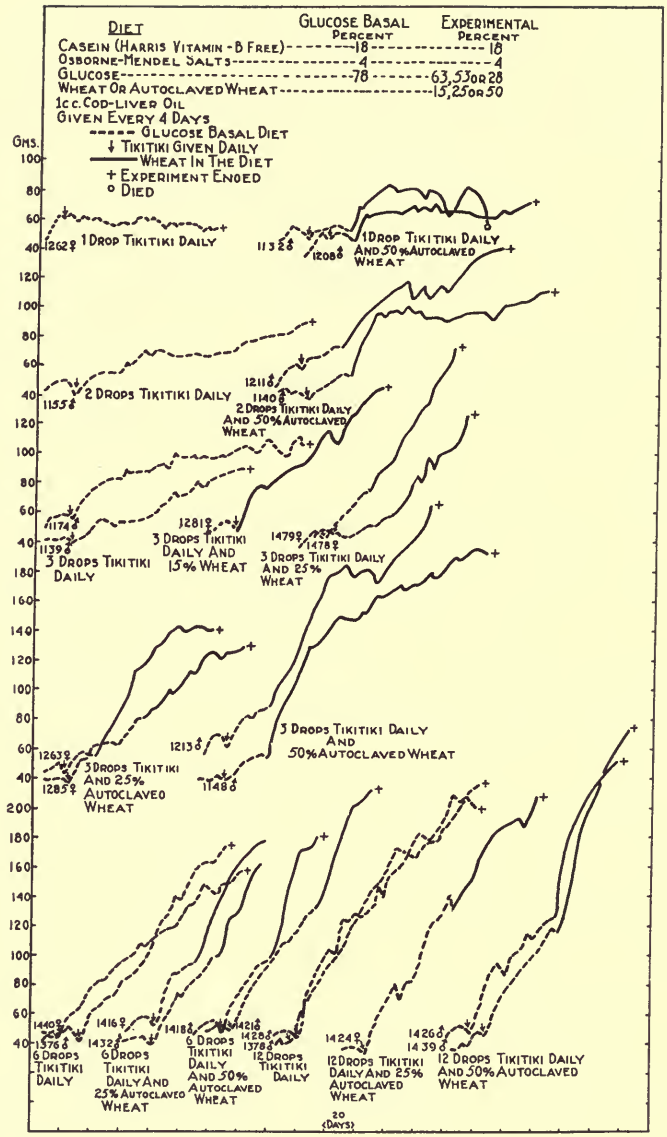

FIG. 10.—WEIGHT CURVES OF RATS RECEIVING UNTREATED OR AUTOCLAVED WHEAT AS SOURCE OF VITAMIN G WITH TIKITIKI SUPPLYING VITAMIN B

Improved growth always occurred when untreated or autoclaved wheat was fed.

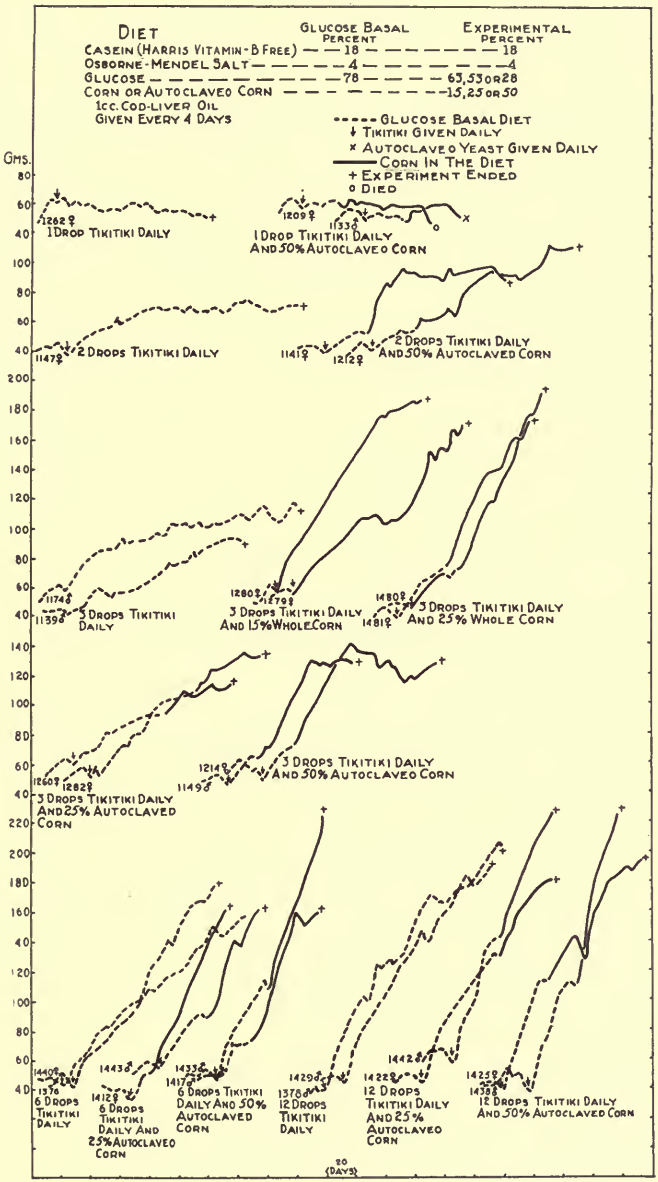

FIG. 11.—WEIGHT CURVES OF RATS RECEIVING UNTREATED OR AUTOCLAVED CORN AS SOURCE OF VITAMIN G WITH TIKITIKI AS SOURCE OF VITAMIN B

Improved growth occurred whenever the untreated or autoclaved cereal was added to the diet.

is thus indicated that a diet consisting of 50 percent autoclaved oats furnishes sufficient vitamin G for growth when sufficient vitamin B is included. The same was found to be true for wheat and for corn.

Oats, wheat, and corn, judging from these results, are comparable in vitamin G content; rice polishings contain a considerable amount

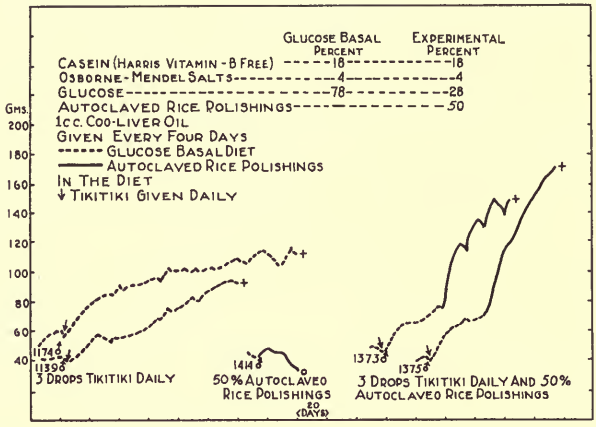

FIG. 12.—WEIGHT CURVES OF RATS RECEIVING TIKITIKI, AUTOCLAVED RICE POLISHINGS, AND TIKITIKI AND AUTOCLAVED RICE POLISHINGS AS SOURCES OF VITAMINS B AND G

The good growth obtained with tikitiki and autoclaved rice polishings indicates the presence of vitamin G in the rice polishings.

of vitamin G. This last finding may be of considerable significance since tikitiki was used thruout the present investigation as a source of vitamin B. Evans and Burr[10]* considered tikitiki a potent source of vitamin B but almost totally lacking in vitamin G. According to Chick and Roscoe[5]* vitamin B_1 (B), the antineuritic vitamin, is soluble in all concentrations of alcohol while vitamin B_2 (G) is soluble only in alcohol concentrations of less than 83 to 93 percent by weight. In view of the fact that tikitiki is a dilute alcoholic extract of rice polishings, it seems possible that it may contain a considerable amount of vitamin G, particularly since it has been shown here that rice polishings contain this vitamin. The fairly good growth obtained when large amounts of tikitiki were fed as the sole source of vitamins B and G support the observation that tikitiki contains vitamin G. Further work is in progress in an attempt to determine the vitamin-G content of tikitiki.

IV. VITAMIN-B AND VITAMIN-G VALUE OF WHOLE HULL-LESS OATS FOR LACTATION

In testing the vitamin-B and vitamin-G value of whole hull-less oats for lactation, adult albino rats were maintained on the diets described in Table 17, in most cases during and for a month preceding pregnancy, and in all cases during the lactation period. Before remating, the rats were kept on the test diet for one month following lactation; as a rule each animal was used for not more than three lactation tests. The animals were mated for four-day periods; the lactation period

TABLE 17.—PERCENTAGE COMPOSITION OF DIETS USED IN RAT LACTATION TEST
(All diets included cod-liver oil given separately in 1-cc. amounts semi-weekly)

Diet	Whole hull-less oats	Corn-starch	Osborne-Mendel salt mixture	Casein (Harris vitamin-B free)	Auto-claved yeast	Tikitiki daily
	perct.	*perct.*	*perct.*	*perct.*	*perct.*	*drops*
1	50	28	4	18	..	..
2	78	..	4	18	..	..
3	50	13	4	18	15	..
4	50	28	4	18	..	6
5	25	38	4	18	15	..
6	25	23	4	18	30	..
7	25	38	4	18	15	6

terminated when the young were 21 days old. On the third day after the birth of the young, the litters were reduced to six.

Raised-bottom cages were used thruout the entire experiment. Specially designed cages, as shown in Fig. 13, were used during the lactation periods. The weights and food intake of the mothers were recorded at four-day intervals during the entire experimental period. During lactation the young were weighed daily; they were considered normal if they weighed 40 grams when they were 21 days old.

The diets that contained whole hull-less oats as a sole source of vitamins B and G proved inadequate for successful lactation (Table 18, Fig. 14). The young of mothers on diets that included 50 or 78 percent oats (Diets 1 and 2) grew and developed at a rate slightly below normal for a period of 10 to 14 days, at which time there was a cessation of growth followed by decreased activity and loss of weight. The young animals sometimes cried out and ran blindly about the cage. Sure[27]* describes this condition as "screaming. running fits." The muscles twitched or became flabby. A typical animal is pictured in Fig. 15. Death usually resulted before the rats were three weeks old.

Success in lactation was obtained with Diet 3, which differed from Diet 1 in that autoclaved yeast, a potent source of vitamin G and

totally lacking in vitamin B, was included with the oats (Table 19, Fig. 16). Litters of rats whose mothers had this diet for the first time were not always normal in weight, possibly because the effect of preceding diets had not been fully compensated by Diet 3 during the time of its ingestion. In the cases of Rats 971 and 1223 the second litters on Diet 3 were heavier at three weeks of age than were the young of the first litter raised on this diet. Young of mothers receiving Diet 3 grew rapidly after weaning, so that even in the litters where the young were below normal weight at three weeks, they soon made up for the weight deficiency. In all cases the young of mothers on this diet—50 percent oats and 15 percent autoclaved yeast for vitamins B and G—appeared to be in better nutritive condition than the young of rats on any of the other diets tested.

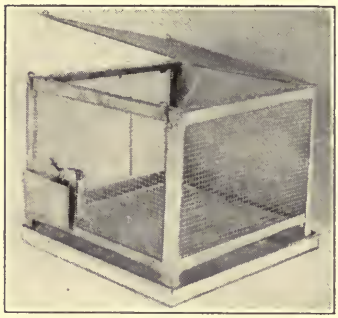

FIG. 13.—TYPE OF CAGE USED DURING LACTATION PERIOD

The animals were left in small cages until just a few days before the young were born. At this time they were transferred to the large cage and allowed to remain thruout the period of lactation.

When Diet 4 (6 drops daily of tikitiki and 50 percent oats for vitamins B and G) was used, there was improvement in lactation over the results when Diets 1 and 2 were used (Table 20). The young raised by mothers on Diet 4 did not appear to be as healthy nor did they gain as rapidly after weaning as the young of mothers on Diet 3. Results reported in Part III of this bulletin showing good growth with 6 drops of tikitiki daily as the sole source of vitamins B and G, indicate that vitamin G is present in tikitiki. In Diet 4 it seems likely that it was the vitamin G of tikitiki which supplemented the oats sufficiently to provide for successful lactation. This conclusion is strengthened by the fact that successful lactation occurred with Diet 3 when autoclaved yeast, a source of vitamin G free from vitamin B, was added to the oats diet.

Diets including 25 percent oats, even when supplemented by 15 or 30 percent autoclaved yeast (Diets 5 and 6), were inadequate for successful lactation (Table 21). When 6 drops of tikitiki were given daily with 25 percent oats and autoclaved yeast (Diet 7), two litters grew almost normally, but again they were not so well developed as the young of mothers on Diet 3. No tests were made using diets con-

TABLE 18.—EFFECTS OF DIETS 1 AND 2 ON LACTATION IN THE RAT, WHOLE OATS ALONE SUPPLYING VITAMINS B AND G

Rat No.	Litter	Average weight of young at 21st day	Condition of young at 21st day
		gms.	
Diet 1; 50 percent oats			
973	1st	Dead	All dead by 17th day after apparently normal initial growth
891	1st	Dead	All dead by 16th day; convulsive muscles and collapse preceded death
1227	1st	Dead	All dead by 3d day
913	1st	Dead	All but 2 dead by 17th day; 2 lived 3 weeks, then died
1039	1st	Dead	All dead by 16th day
1035	1st	Dead	All dead by 16th day
1059	1st	Dead	All dead or dying by 17th day
971	1st	Dead	3 dead by 18th day, rest died in week following
1223	1st	Dead	All dead by 17th day
895	2d	26.5[1]	4 young
895	3d	Dead	All dead or dying by 17th day
Diet 2; 78 percent oats			
1035[2]	2d	30	Small but good
1035	3d	Dead	Lived 4 days
1227[2]	2d	Dead	All dead by 16th day
1227	3d	Dead	All dead by 18th day

[1]First litter with Diet 1 and egg yolk. [2]First litter with Diet 1.

taining oats at levels between 25 and 50 percent for the sole source of vitamin B, but it is probable that 50 percent oats is the least that will provide for optimum lactation since even 6 drops of tikitiki daily, in addition to Diets 5 and 6, did not furnish enough vitamin B to make these diets entirely comparable with the 50 percent oats and 15 percent autoclaved yeast diet (Diet 3).

TABLE 19.—EFFECT OF DIET 3 ON LACTATION IN THE RAT, WHOLE OATS (50 PERCENT) AND AUTOCLAVED YEAST (15 PERCENT) SUPPLYING VITAMINS B AND G

Rat No.	Litter	Average weight of young at 21st day	Condition of young at 21st day
		gms.	
1000[1]	2d	32	Small but good
971[2]	2d	37	Very good
971	3d	40	Very good
1223[2]	2d	24	Tails with severe lesions
1223	3d	37	Very good
1225[3]	3d	34	Very good
1086[4]	3d	41	Very good
1222[5]	3d	40	Very good
1463[6]	1st	32	Small but very good

[1]After 1 unsuccessful litter with Diet 5. [2]After 1 unsuccessful litter with Diet 1. [3]After 2 unsuccessful litters with Diet 1 and lettuce. [4]After 2 unsuccessful litters with Diet 1 and lean beef. [5]After 2 unsuccessful litters with Diet 1 and egg white. [6]This animal was raised on a diet in which 50 percent oats and .4 gram autoclaved yeast daily supplied vitamins B and G. Diet 3 was not given before the animal was pregnant. An abnormal condition of the tail made it necessary to kill the animal before a second litter was produced.

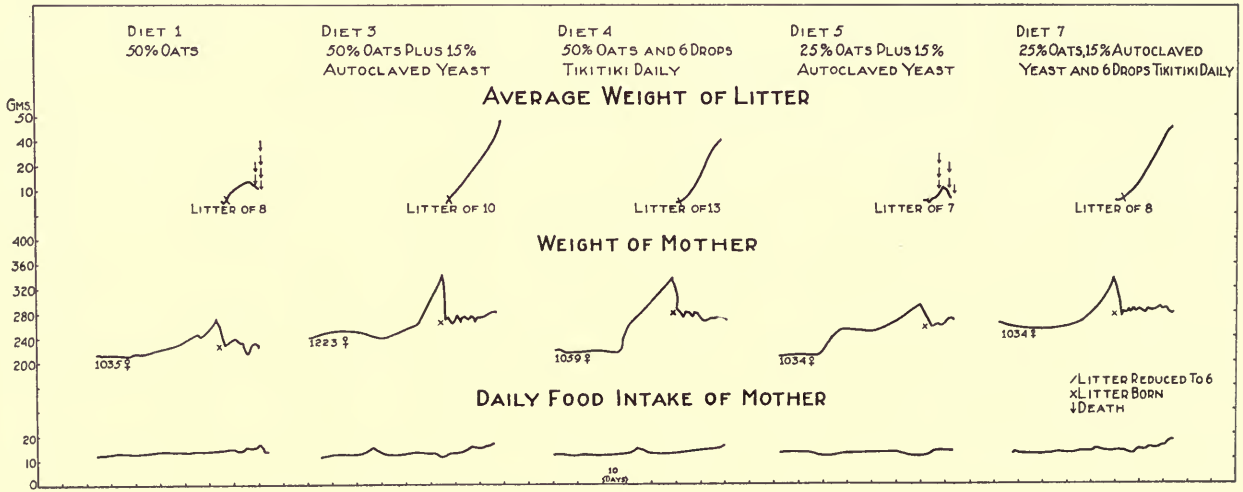

FIG. 14.—AVERAGE WEIGHT CURVE OF LITTER AND WEIGHT CURVE AND DAILY FOOD INTAKE OF MOTHER RAT ON DIETS 1, 3, 4, 5, 7

Oats, oats and autoclaved yeast, oats and tikitiki, and oats with autoclaved yeast and tikitiki were the sources of vitamins B and G for lactation.

It may be concluded from the above observations that it is possible to include enough oats (50 percent) in the diet of a rat to furnish sufficient vitamin B for successful lactation. On the other hand, it

FIG. 15.—TYPICAL YOUNG OF RAT 913 ON DIET 1 WHICH INCLUDED 50 PERCENT OATS FOR VITAMINS B AND G

When the picture was taken, this animal was 17 days old and weighed 16 grams. It died the same day.

was found impossible to furnish sufficient vitamin G for successful lactation when oats were the sole source of this vitamin in the diet, as demonstrated by the lack of success with both Diets 1 and 2. In the latter case 78 percent oats were used, or the maximum amount possible without altering the composition of the diet with respect to salt

TABLE 20.—EFFECT OF DIET 4 ON LACTATION IN THE RAT, WHOLE OATS (50 PERCENT) AND TIKITIKI (6 DROPS) SUPPLYING VITAMINS B AND G

Rat No.	Litter	Average weight of young at 21st day	Condition of young at 21st day
		gms.	
1039[1]	2d	29.0	Small but good
1059[1]	2d	31.5	Small but good
1473	1st	40.0	Good (5 young)
1643	1st	Dead	All dead by 7th day

[1]First litter with Diet 1 was unsuccessful.

mixture and casein content. The above findings are particularly significant since the results reported in Part II of this bulletin demonstrate that a diet including 25 percent oats when supplemented with autoclaved yeast is adequate in vitamin B for growth approaching normal, while the results discussed in Part III indicate that a diet including 50 percent oats is adequate in vitamin G for good growth.

Macy, Outhouse, and Long[15]* in 1927 stated that three to five

times as much vitamin B is necessary for lactation as for growth. These investigators used yeast as the source of vitamin B but the work was carried on before the final recognition of vitamin G. Apparently it was the vitamin G of yeast which was an important factor in promoting successful lactation. Evans and Burr[9]* in 1928 made the follow-

FIG. 16.—TYPICAL YOUNG OF RAT 971 ON DIET 3 WHICH INCLUDED 50 PERCENT OATS AND AUTOCLAVED YEAST FOR VITAMINS B AND G

When the picture was taken this animal was 21 days old and weighed 40 grams.

ing statement: "The indications are that when yeast is the accessory source of vitamin B about five times the usual intake is required during the latter part of the lactation period." They state further that "the additional yeast needed for lactation is solely due to its addition

TABLE 21.—EFFECTS OF DIETS 5, 6, AND 7 ON LACTATION IN THE RAT, WHOLE OATS AND AUTOCLAVED YEAST OR WHOLE OATS, TIKITIKI, AND AUTOCLAVED YEAST SUPPLYING VITAMINS B AND G

Rat No.	Litter	Average weight of young at 21st day	Condition of young at 21st day
Diet 5; 25 percent oats, 15 percent autoclaved yeast			
		gms.	
1000	1st	Dead	All dead by 16th day
1041	1st	Dead	All dead by 17th day
1034	1st	20.5	4 young, small
1034	2d	Dead	All dead by 12th day
Diet 6; 25 percent oats, 30 percent autoclaved yeast			
1041	2d	Dead	Lived 4 days
1041	3d	Dead	Lived 2 days
Diet 7; 25 percent oats, 15 percent autoclaved yeast, 6 drops tikitiki daily			
1034	3d	32.7	Good
1034	4th	25.5	Grew slowly

to the antineuritic vitamin B and not to the growth-promoting vitamin B of the diet, for when tikitiki is given to lactating mothers without increased yeast dosage we can also produce normal lactation." These investigators used tikitiki and yeast as sources of vitamins B and G, but at that time it was thought that tikitiki contained no vitamin G. Sure[27]* in 1928, using rice polishings and autoclaved yeast as sources of vitamins B and G, concluded that both these vitamins are necessary for successful lactation. Hussemann and Hetler[14]* showed that equally successful lactation is possible when 5 percent yeast and 15 percent

TABLE 22.—AVERAGE DAILY FOOD INTAKE OF RATS AS AFFECTED BY VARIATIONS IN SOURCE OF VITAMINS B AND G IN DIET DURING RESTING, PREGNANCY, AND LACTATION

Rat No.	Litter	Average daily food intake during resting	Average daily food intake during pregnancy	Average daily food intake during lactation
		Diet 1; 50 percent oats		
		gms.	*gms.*	*gms.*
1059	1st	12.3	15.2	19.3
973	1st	13.8	15.0	14.8
1039	1st	13.5	10.6	13.5
1227	1st	....	12.8	7.0
971	1st	....	....	15.2
895	3d	11.4	10.4	12.6
1223	1st	....	12.5	15.0[1]
		Diet 2; 78 percent oats		
1035	2d	15.4	12.5	24.4
1035	3d	13.4	13.5	15.6
1227	2d	11.1	14.3	17.4
1227	3d	13.8	14.4	12.1
		Diet 3; 50 percent oats, 15 percent autoclaved yeast		
971	2d	17.0[2]	13.2	24.0
971	3d	11.0	12.2	31.0
1223	2d	9.6	13.5	21.0
1223	3d	13.5	13.8	26.2
1086	3d	17.5	17.5	27.6
1000	2d	12.3[3]	15.3	19.0
		Diet 4; 50 percent oats, 6 drops tikitiki daily		
1059	2d	17.3[2]	15.2	21.8
1039	2d	14.6[2]	14.6	16.3
1473	1st	....	9.7	24.9
		Diet 5; 25 percent oats, 15 percent autoclaved yeast		
1000	1st	9.8	16.5	22.2
1034	1st	12.8	17.0	20.9
1034	2d	15.0	15.0	12.7
1041	1st	....	13.5	18.8
		Diet 6; 25 percent oats, 30 percent autoclaved yeast		
1041	2d	15.2[3]	11.4	8.0
1041	3d	14.6	15.0	13.3
		Diet 7; 25 percent oats, 15 percent autoclaved yeast, 6 drops tikitiki daily		
1034	3d	12.1	16.0	25.7
1034	4th	11.2	16.0	25.1

[1]Diet 3 given at end of first week of lactation. [2]Diet 1 during resting period. [3]Diet 5 during resting period.

autoclaved yeast furnish vitamins B and G, as when 15 percent yeast is used for these vitamins. They have also demonstrated better success in lactation with 5 percent yeast and tikitiki than with 5 percent yeast alone. But before the results with tikitiki as a supplement can be evaluated in terms of vitamins B and G, it will be necessary to have more exact data concerning the vitamin-G content of this product. The results obtained by Hussemann and Hetler and the results of the present investigation indicate, however, that more vitamin G is necessary for successful lactation than for normal growth. Roughly one might estimate that about twice as much vitamin B and three or four times as much vitamin G are required for lactation as for growth.

A study of the results here presented of the use of oats as a source of vitamins B and G for lactation is not complete without a consideration of the food intake of the animals (Table 22). The average daily food consumption for any one animal was almost constant during the resting and pregnancy periods. A slight increase during pregnancy occurred in some cases, but with other animals less food was eaten during pregnancy than during the resting period. A marked rise in food intake was noted, however, during the lactation period in the cases where success in the development of the young resulted. When Diets 1 or 2, 50 or 78 percent oats, were fed, or when Diets 5 and 6, 25 percent oats with autoclaved yeast, were given, there was little if any increase in food consumption during the lactation period. Lactation was unsuccessful with these diets, in which vitamin B or vitamin G was the limiting factor. Whether the low food intake was entirely responsible for the failure in the nursing of the young, or whether the lack of stimulation to appetite was a direct contributing factor owing to the deficiency of vitamins B and G, is a subject for further investigation. Whenever lactation was successful, however, a marked stimulation of appetite and rise in food intake of the mother always occurred during the nursing period.

SUMMARY

The vitamin-B and vitamin-G value of oats and oat products, corn, wheat, rice polishings, and tikitiki, was studied by determining the growth rate of albino rats when the cereal or cereal product furnished the sole source of these vitamins in the diet. Vitamins B and G, originally known as vitamin B and later as the vitamin-B complex, were both found to be present in the cereals and cereal products studied. The work of Smith and Hendrick (1926),[24]* of Sherman and Axtmayer,[22]* and of Hunt (1928),[13]* showing that vitamin G is the limiting factor

of the vitamin-B complex of cereals, was confirmed. It was found, however, that a diet including 50 percent of any of the cereals would supply enough of the heat-stabile vitamin G for approximately normal growth, while 25 percent of any of the cereals provided enough vitamin B. It was indicated that vitamin G is present in tikitiki.

In earlier work in the Home Economics laboratory at the University of Illinois, before the identification of vitamin G, a study was made of the location of the vitamin-B complex in oats. It was found that vitamin B, old nomenclature, is distributed thruout the oat kernel but occurs in greater concentration in the embryo than in the endosperm section.

Study was made of the vitamin-B and vitamin-G value of oats for lactation in the rat. If a diet containing 50 percent oats was used for vitamin B, successful lactation occurred. However, when oats were the sole source of vitamin G in the diet, it was impossible to furnish sufficient vitamin G for successful lactation.

Methods are described for testing for vitamin B and for vitamin G. Autoclaved yeast was used to furnish vitamin G in the vitamin-B test, and tikitiki was used to furnish vitamin B in the vitamin-G test. A basal diet which included vitamin-free casein, Osborne-Mendel salt mixture, and glucose was found satisfactory both for vitamin-B and for vitamin-G determinations. Cod-liver oil was fed separately. When a diet containing Crisco and cornstarch instead of glucose was used for the vitamin-B tests, a somewhat higher level of any of the cereals was necessary to furnish sufficient vitamin B for good growth.

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